ELECTRICAL ENGINEERING

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HIGH-LIGHTS • •

Single-Pole Reclosing. A single-pole operation has been developed recently to replace the usual three-pole operation for high-speed tripping and reclosing of transmission-line circuit breakers. The chief relay problem created by the new type of operation has been solved by the development of a relay composed of three selector elements similar to a conventional directional element (*Transactions pages 77–81*). Tests have been conducted on what is said to be the first application of single-pole reclosing in the United States to check for both arcing and solid faults at various points on the system (*Transactions pages 81–7*).

200-Inch Telescope. A million light-years is the distance to which the 200-inch telescope now nearing completion on Palomar Mountain, Calif., is expected to penetrate space. Although the structure is of huge proportions for a telescope and weighs thousands of tons, it must have the accuracy of the finest watch, in order to remain focused on a star during a long photographic exposure. An elaborate electrical control and drive system provides the required accuracy (*pages 67–78*).

Circuit-Breaker Testing. Field tests on a 1,500,000-kva 15-kv air-blast circuit breaker confirmed preliminary indications given by tests with a synthetic circuit in the factory (*Transactions pages 100–04*). The testing laboratory of a manufacturing company has added a second 60,000-kva generator and additional transformers, extending the available voltage for testing high-capacity breakers to 345 kv three phase, or 396 kv single phase with the neutral grounded (*Transactions pages 49–53*).

Mathematics for Electrical Engineers. A series of lectures on advanced methods of mathematical analysis as applied to electrical engineering, presented as a symposium under auspices of the basic science group of the AIEE New York Section, are being published in *Electrical Engineering*, and eventually will appear in combined pamphlet form. First of the series deals with applications of Heaviside's direct operational calculus (*pages 84–8*).

Welding Transients. Oscillograms of current and power in resistance welding have shown that in the first few cycles after random switching the heat input to the weld may vary as much as 50 per cent; but that as the number of cycles increases, the heat error caused by transients decreases and in weld periods of more than one third second may be disregarded (*Transactions pages 94–5*).

Regulating Voltage. New types of voltage-regulating devices that have been developed include a static voltage regulator supplying a constant output voltage independent of load power factor (*Transactions pages 67–70*), and a voltage-regulating relay with line-drop compensator which corrects for magnitude and phase angle of the line drop (*Transactions pages 63–6*).

Power-Line Carrier Current. A carrier-current system in service on a high-voltage power line provides a relatively large number of channels; methods employed include special precautions to prevent faulty tripping of the line as a result of external disturbances that might generate carrier-current tripping impulses (*Transactions pages 71–6*).

Evening Study for Graduate Engineers. One of the most promising ways of meeting the need for highly trained engineers in the war effort is through instruction in evening courses of graduate engineers already in industry; the experiences of an engineering educator in organizing and supervising such courses has been outlined (*Transactions pages 88–94*).

Demand Measurement. The thermal-storage method of measuring the maximum demand for electric service by a user has been compared with the more commonly used block-interval method, which is subject to a possible error of 50 per cent (*Transactions pages 57–62*).

Protecting Substations. As part of a general investigation of lightning protection, recommendations have been made for the location of overhead ground wires and vertical masts to provide adequate shielding for substation structures (*Transactions pages 96–100*).

Electrical Drives. Addition of a rotating regulator to a conventional variable-voltage system has been found to provide an electrical drive with a speed range of 120 to 1, which can be used in many industries to simplify the mechanical design of the machine it drives (*Transactions pages 54–6*).

Automatic Washing-Machine Control. Engineering features of a domestic washing-machine unit designed to require a minimum of attention have been described; automatic control extends to all operations (*pages 89–92*).

Lighting for Protection. What is regarded as ordinary good practice in outdoor lighting for many types of industrial plants takes on added significance in time of war (*pages 80–3*).

Letters to the Editor. Among subjects discussed in the "Letters to the Editor" columns of this issue are the standardization of dielectric nomenclature (*pages 105–06*); a method of developing vector equations from laboratory data (*pages 107–09*); a graphical aid for the multiplication and division of complex numbers (*pages 104–05*); the recently published report on ten years of progress in relaying (*page 106*); and others.

Subcontracting Field Offices. A list of the field offices set up to facilitate wider distribution of war-production contracts has been prepared, with the names of managers and addresses of the offices (*pages 99–100*).

1941 Defense Production. An authoritative review of United States production for defense purposes in 1941 shows how pre-Pearl Harbor production compared with that of the Axis nations (*pages 100–01*).

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article on modern railroad-car lighting by W. S. H. Hamilton (M'26); an article on integration in the complex plane by K. O. Friedrichs, the second in the series on advanced mathematics as applied to electrical engineering; the addresses delivered at the Edison Medal presentation during the 1942 AIEE winter convention; a paper describing a fast circuit breaker by D. I. Bohn (M'41) and Otto Jensen (A'41); two papers on large wind-tunnel drives with adjustable speed, one by C. C. Clymer, and one by A. M. Dickey, C. M. Laffoon (M'39), and L. A. Kilgore (M'37); a paper discussing overhead distribution systems in wartime by Harold Cole (M'27); a paper on underground distribution systems in wartime by L. R. Gaty (A'39); a paper on electropneumatic brakes for high-speed trains with particular reference to their electrical features by Joseph C. McCune; a paper on current loci for the capacitor motor by T. C. McFarland (M'32); a paper describing a control system for modern multiple-unit rapid-transit cars by H. G. Moore (A'38); a paper on distribution substations and wartime necessities by F. C. Poage (M'38) and M. W. Reid; a paper on power supply to distribution substations in wartime by H. P. St. Clair (M'29); a paper on utilization voltages by Howard P. Seelye (M'28); a paper on progress in design of electrical equipment for large Diesel-electric locomotives by Gerald F. Smith (A'13); a paper on the influence of towers and conductor sag on transmission-line shielding by Royal W. Sorensen (F'19) and Robert C. McMaster (A'39); a paper on electric-power distribution systems in wartime by Philip Sporn (F'30); and a paper on hot-spot winding temperatures in self-cooled oil-insulated transformers by F. J. Vogel (M'41) and Paul Narbutovskih (A'32).

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Electrical Features of the 200-Inch Telescope

BRUCE H. RULE
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BRIEFLY, the function of the Palomar Mountain 200-inch telescope is to collect light from celestial objects and concentrate it at the prime focus, or, by a series of additional reflections from auxiliary mirrors, bring the light to other focal points both on and off the telescope. The major advantages of the 200-inch telescope over other large telescopes are: (1) its considerably larger light-gathering capacity, permitting reduction in time of exposures and the photographing of more distant objects; (2) its design, permitting astronomical work directly on the telescope at the prime focus, thus avoiding the loss of light through additional reflections; (3) its flexibility by remotely operated auxiliary mirror combinations; and (4) its automatically corrected drive and setting controls.

To realize the optical advantages of the 200-inch telescope now being constructed atop Palomar Mountain in Southern California, a complicated electrical control and drive system has been devised. Although necessarily of huge proportions, in order to accommodate the 200-inch mirror, the instrument must possess the accuracy of the finest watch, and the necessary co-ordination of the precise mechanisms comprising the instruments could be achieved only by electrical means. The unprecedented and unusual control problems involved have been solved by modifications of conventional methods or development of new control devices to meet special conditions.

The vital part of the instrument, of course, is the 200-inch mirror of 14½ tons of glass, which is supported on a 530-ton mounting so that it can be directed with minimum effort toward any point of the celestial hemisphere and moved automatically and continually to follow the apparent motion of the stars. The star image must remain stationary on a photographic plate, or spectrograph slit, for the entire period of exposure, which may be several hours. The weight and size of the mounting is not overwhelming compared with modern structures, but the high optical and drive accuracy required makes the design problems unusual. For example, while a structure of comparable size may safely deflect several inches under load, the telescope tube must not deform in any position more than 1/16 inch and the face of the mirror must remain perfect to within two-millionths of an inch. Added to these rigid optical-alignment requirements are the drive and setting control functions which must compensate for the residual structural deformations, periodic driving-gear errors, errors due to atmospheric refraction, unbalance, and other operations, all of which are functions of hour angle (about the polar axis) and declination angle. Also to be co-ordinated with the telescope position are the operations of various auxiliary equipment, such as the rotating dome, dome shutter, prime-focus elevator, wind screen, hoists, and moving platforms, each involving some unusual control problem.

The general assembly of the telescope and its auxiliaries is shown in Figure 1. In the upper cartridge-like cage the observer rides in a level position at the prime focus (*f*3.3), regardless of the orientation of the tube. The photographic plate is supported on an extension of the mirror-cell cage immediately below (shown in Figure 3) so that light from the 200-inch mirror in the lower end of the tube reaches the photographic plate with but one reflection. Contained in this lower cage are three convex auxiliary mirrors, together with mechanisms for swinging them into and out of position, automatic counterbalancing, uncovering mirrors, and focusing the unit as a whole. One of these convex mirrors is the Cassegrain mirror which brings the light to a focus (*f*16) below the 200-inch mirror. The other two convex mirrors are used in a three- or five-mirror Coudé combination which, by means of a flat mirror at the center of the declination axis, brings the light to the Coudé focus (*f*30) located in a separate pedestal room directly south of the telescope mounting. The two inner cages are supported on independent "knife edges" from the outer 22-foot structural cage which may be rotated and clamped at intervals of 22½ degrees. The prime-focus observer has complete control of the telescope's motions.

At the Cassegrain focus, immediately below the hole in the 200-inch reflector, will be installed a four-foot prism spectrograph, or other instruments that may be raised into position by a central hydraulic hoist. Here the observer will sit on a movable platform raised to 32 feet by hydraulic plungers supported on a truck carriage that may be moved in any direction at will.

By means of a crane on the north panel of the tube, the Coudé flat mirror may be swung down into place over the three-foot-diameter Cassegrain tube extending from the central portion of the main mirror. The flat mirror is automatically clamped into place and the crane

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Definition of Terms

The following astronomical terms are derived from a celestial sphere having poles, equator, and meridian:

Hour Circle. A great circle on the celestial sphere passing through the poles.

Meridian. The hour circle passing through the zenith.

Hour Angle. Angle at the pole between the meridian and hour circle through the observed object; or time since object was at upper transit; 15 degrees equivalent to one hour.

Vernal Equinox. Point where the sun, in its apparent annual motion crosses the equator from south to north.

Sidereal Time. Hour angle of the vernal equinox.

Right Ascension. Arc distance in units of time, measured eastward from the vernal equinox to foot of hour circle through the object; that is, equal to sidereal time when object is at upper transit.

Declination. Arc distance along hour circle from equator to object, north being plus, and south minus.

Zenith. Point of celestial sphere directly overhead.

Zenith Distance. Arc distance from zenith to object.

Optical Terms

f Ratio. Ratio of focal length to aperture.

Prime Focus. Image at one reflection from paraboloidal primary mirror.

Cassegrain Focus. Paraboloidal primary and hyperboloidal secondary mirror; image is below primary mirror.

Coudé Focus. Final light path is along polar axis of telescope and hence stationary when telescope moves.

Miscellaneous Terms From Naval Usage

Slewing. The process of rapidly turning about the axis of rotation for quick setting to a new position.

Tracking. The process of following a given object through all of its apparent motions.

returns to the north panel. By remote control, this mirror may be rotated about the telescope tube axis to reflect the converging light beam from the prime-focus convex Cassegrain (*f*16) mirror, through the east hollow declination trunnion into the 10-foot east yoke tube, where an eight-foot plane-grating spectrograph is provided for. This spectrograph will be mounted on a pivoted table which remains level, together with the observer's stairway, as the yoke moves on its axis. The flat mirror also may be tilted remotely by hand, or automatically as a function of half the angle of declination; this movement allows the reflection of the light beam through the polar axis to the Coudé focus (*f*30) as mentioned. When this diagonal flat mirror is not required, the crane raises it against the north face of the tube out of the way, by remote control from a balcony mirror-control pulpit shown at the left of Figure3. Any desired combination may be brought into use within a few minutes.

Previous publications have aptly described the design and construction of the yoke-type mounting,[1–3] its polar oil-pad bearings, declination-trunnion bearings, and driving gears.[4] Further discussion of these features therefore is omitted here, except as it affects the description of the electrical features.

GENERAL CONTROL REQUIREMENTS

The large size of this telescope has made necessary a more elaborate control system than heretofore has been used. In general, the control was designed to be operationally simple and to relieve the observers of any unnecessary tasks during observations.

To justify the expense of such a large instrument, every moment of good "seeing" time must be used to its fullest extent in getting good photographs, with no time wasted in setup operations and adjustments. Thus, special attention is being paid to reducing the time necessary to change the auxiliary-mirror combinations for work at different focal points. Instead of changing cages at the top of the tube, as has been done before, all mirrors will be permanently attached to the telescope and will be swung into and out of position by means of motorized mechanisms. Besides placing these mirrors in operating positions by remote buttons, the controls provide for setting the telescope position into the desired field of view automatically. These operations extend the usable time of this large camera and give the flexibility desired for a wide range of uses to meet present and possible future astronomical programs.

Since for the first time the observer will "ride" on the telescope, the usual graduated circles for reading declination angle and hour angle must be modified to allow him to ascertain the telescope setting while working at the various stations. It is desirable also to read the true position of the object viewed through the telescope in right ascension instead of hour angle, as previously done. These conditions among others led to the adoption of a Selsyn remote-indicating system of high accuracy for the right-ascension and declination-angle dials at each observing station. A total of 68 Selsyn units is required for these position indicators and for control functions.

Figure 1 (facing page). Sectional view of telescope and dome, cut away along a vertical plane through the polar axis

The tube weighs about 140 tons, the entire instrument 500 tons, and the rotating dome 1,000 tons

A—200-inch mirror
B—Prime focus, f3.3
C—Cassegrain focus, f 16
D—Coudé focus, f30
E—Coudé and Cassegrain mirrors
F—Declination axis
G—Right-ascension drive
H—Electrical-control panels
I—North control desk
J—Telescope cage
K—Prime-focus platform from which observer gets on and off tube
L—North polar-axis bearing
M—North pressure bearings
N—South polar-axis bearing
O—Dome trucks
P—Dome drive
Q—Dome shutter, 30-foot opening
R—Passenger elevator
S—60-ton crane
T—Observation floor, 5,598 feet above sea level
U—Offices
V—Constant-temperature room

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Q
K
L
M
R
A
D
T

Figure 2. Telescope tube with equipment assembled

Table I. Telescope Drive Constants

	Right Ascension	Declination
Angular Limits (Degrees)		
Mounting	±105	N +91
Tube—arch-crane down		S −57
Tube—arch-crane up		S −43
Tube—above horizon slew limit	5	5
Tube—above horizon final limit	2	2
Phantom limits (artificial horizon)	5	5
Movements		
Tracking velocity, seconds of arc per second	15	
Guiding velocity, seconds of arc per second	1.5	1.5
Setting velocity, seconds of arc per second	40	40
Slewing velocity, degrees per minute	45	45
Slewing acceleration and deceleration, degrees per minute per second	4.5	4.5
Corrections		
Limits, seconds of arc		+50 −100
Maximum velocity, seconds of arc per hour	270	270
Time constant, seconds	15	15
Maximum superposed rate, seconds of arc per hour	2,700	1,000
Speed Range		
Manual, low to high	1/1,800	1/1,800
Automatic, low to high	1/36,000	1/36,000
Rate of Electric Drive		
Maximum accumulated errors, seconds of arc per hour	1.0	1.0
Maximum momentary error, seconds of arc per 5 seconds	0.1	0.1
Over-all setting accuracy, seconds of arc (within 45 degrees of zenith)	5.0	5.0

Table I shows the constants of the drive and setting mechanisms for the telescope. All operations must be performed reliably and with provisions for manual control where automatic equipment may fail. Important auxiliaries are provided in duplicate to minimize loss of observing time caused by outages or maintenance work. Alarms and indicator lights must warn of unusual or dangerous positions of mechanisms, and controls must be interlocked to allow only the correct sequence of operations. The observer may set up various auxiliary mirrors and equipment from the main control points on the floor, but during the time of exposures all operations of necessity are performed in darkness by the observer on the telescope; hence hand control devices are reduced to the safest minimum consistent with the operations required for guiding the telescope and protecting the observer.

Power requirements are not in proportion to the size of the telescope structure, for most of the 60-odd motors are of fractional horsepower, the right-ascension tracking motor being 1/12 horsepower and the others varying from 3 horsepower for slewing (fast setting motion) down to 1/2,000 horsepower for sidereal time rate dials. Nevertheless, because of the long wire runs and severe bending and twisting requirements for wire between moving sections, the number of conductors and their size must be kept to a minimum. By simplifying various drive mechanisms and controls to allow small motors to

Figure 3. Prime-focus mirror cage assembled for tests with control pulpit

be used wherever possible, and by using mostly three-phase motors, the wires in various flexible cables were kept to a minimum in number and size. Approximately 100 miles of conductor is installed for the telescope's power and control, including over four miles of slip-ring bars, ten miles of extraflexible wires in bending, three miles of extra-flexible wire in torsion cables, and two miles of flexible wire in plug connections. Most of the wire in the assembled wire-armored cables had to be attached to and follow the structural members of the telescope, terminating in equipment boxes at accessible locations.

A one-line diagram of the power and control distribution system is shown in Figure 4. All of the control and power wires and their associated relays and devices are laid out for a minimum of maintenance over a long expected duty life, and to provide for easy replacement and extension as new devices may be added.

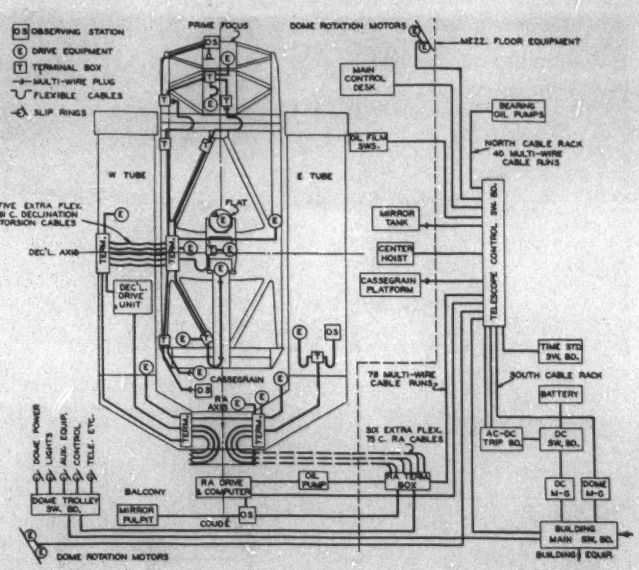

Figure 4. One-line diagram of telescope power-distribution and control circuits

Conventional methods of control have been employed wherever possible; however, the requirements limit the choice of equipment commercially available, and required in many cases development of suitable devices to do the job.

TELESCOPE ELECTRICAL CONTROLS

As outlined in Table I, the smooth and precise drive required for the telescope involves the co-ordination of many drive elements and electrical indicating devices which are assembled in two boxes, one for declination drive in the west tube as shown in Figure 5, the other for right-ascension drive and computer in the cabinet below the south-pedestal cross member, as it appears in Figure 7. In each of these boxes is included the necessary gearing for guiding, setting, and slewing drives, together with the Selsyn transmitters and receivers, correcting-rate drive, superposed-rate drive (for moon, planets, comets, etc.) rate integrators, clutches, and electrical limits. The right-ascension cabinet contains, in addition, the necessary tracking drive, sidereal time rate, computers for right ascension and declination, phantom telescope to duplicate the movements of the main tube, and an automatic printing recorder of position and guide operations.

The declination unit drives through a secondary gear box to the single 173-inch-diameter, 720-tooth worm gear attached to the 55-foot telescope tube. Two gears of the same dimensions, supported on bearings from the south pier, drive the telescope in right ascension through a diaphragm and torque tube. Since the desired accuracy of drive is one second of arc in one hour of time at one revolution per day, and the periodic error is limited to 0.1 second of arc per 5 seconds of time, extreme precision in cutting these gears was required. One second of arc is equivalent to only 0.000445 inch on the pitch circle of the gear.

Two gears bolted together are used for the right-ascension drive, one for slewing (fast motion) 1/8 rpm and the other for tracking and setting at slow speed, thus allowing a minimum of wear on the "fine" worm wheel. Clutching of the proper gear is accomplished by taking up the end thrust on the driving worm to be used. The lower section of Figure 8 indicates that the clutch pin, in the form of a differential-area hydraulic ram, may be moved by oil pressure controlled by the solenoid-operated valves, *AV* and *BV*. Only that worm and wheel with the fixed end thrust will carry load; the other worm "floats."

It may be noted that further use of the floating worms is to be made in "weighing" the telescope for balance. This procedure will require energizing both valves *AV* and *BV* thus providing the proper forces on the pin clutch to hold it at the center of its travel, at the same time providing oil pressure for two hydraulic pistons that

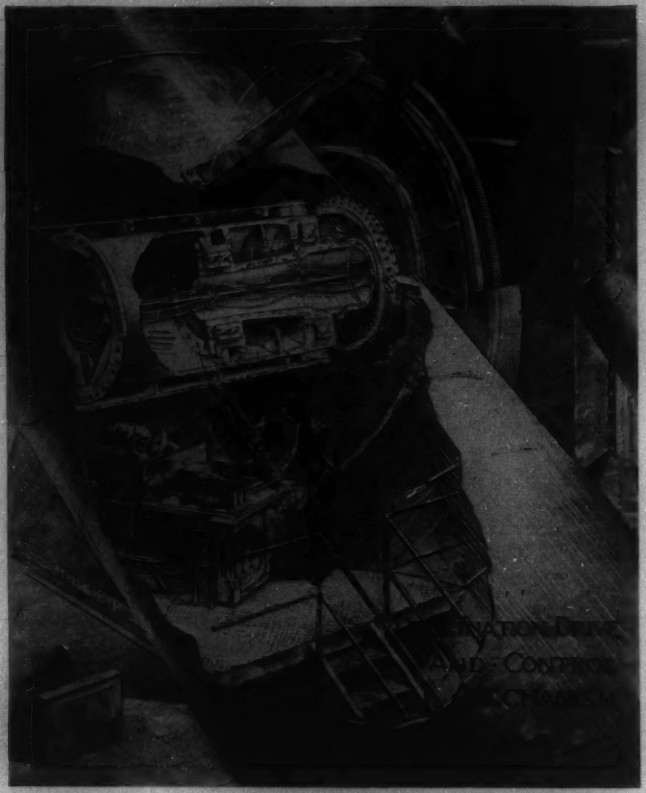

Figure 5. Section through west tube showing torsion cables and declination drive unit below

bear directly on the worm case. The balance of the telescope about the polar axis may then be determined by driving the worm in alternate directions and noting each of the piston gauge pressures. Proper compensation may be made by operating motorized counterweights on both the tube and yoke.

As a final protection against mechanical overload, both right-ascension and declination drives are frictionally held in a reference position. These references are "marked" by precision limit switches which disconnect controls and sound alarms whenever either of them slips. Hydraulically operated jacks provide damping to absorb shock movement and also provide the means necessary to reset to the reference positions.

Referring again to Figure 8, only the essential control and mechanical elements of the right-ascension drive unit have been shown. During the comparatively high-speed slewing operations, all tracking, guiding, setting, and correcting operations are declutched by a zero-speed switch. In slewing, both tube and yoke, the acceleration rate is controlled by the torque characteristics of the motor and the flywheel which is made large compared with the telescope inertia to "mask out" bearing-friction effects. The motor brake provides the proper deceleration torque and is used only for that purpose. The remainder of the motors are coupled through differential gearing approximately as shown.

The computer, briefly, receives hour angle and declination angle from the telescope, and in case of the right-ascension drive ht, introduces an angular correction Δh, which is made up of several factors necessary in order that the telescope may follow the apparent position of a star. These factors include compensation for atmospheric refraction, gear errors, telescope structural deformation, and periodic errors that may be found later. This correction output will be used to regulate the tracking rate as shown in Figure 9.

This computer also will introduce the correction in position upon setting the telescope on a new star. The correction increment Δh added to the hour angle ht through a differential gives the correct hour angle h which, by comparing with the sidereal time T, gives the true right-ascension angle (RA) being observed. This angle is read at all observing stations by precision Selsyn receivers in groups of three, one each for hours, minutes, and seconds. A similar system is used in declination reading degrees, minutes, and seconds (Figure 6).

By setting a similar group of transmitter Selsyns at the control desk to the desired position in hours, minutes, and seconds, and comparing this position received at the south box with the existing right-ascension position, the controls automatically bring the telescope to the desired position with all corrections included. Preliminary tests on the declination drive unit show these automatic set-

Figure 6 (above). Declination drive and control mechanism

tings may be accurate to five seconds of arc.

It may be noted that the observer will have full hand control, except when automatic settings are being made (Figure 8). The four directions, north, east, south, and west, are controlled at three speeds with only seven wires to the small portable hand controller.

One other feature of the right-ascension computer is the phantom or "dummy" telescope, comprising an arm corresponding to the telescope tube, pivoted with two axes of rotation such that it reproduces the real telescope motions. This mechanism has several functions: (1) a set of contacts made near the horizon in the several directions provides an artificial horizon "limit" control for the automatic telescope motions; (2) by transmitting the rotation (about the zenith) to the dome drive unit for comparison with the dome position, the dome can be made automatically to follow the telescope, to keep the shutter slot opening always in the same line with the telescope tube; (3) the movement of the arm from the zenith carrying a voltage-divider slider provides the remote meter indications of zenith distance; (4) the same zenith-distance is compared with the wind-screen-position voltage divider to provide automatic control and keep the canvas wind screen following the telescope up or down.

To provide for a variable corrected drive to move the telescope in hour angle at approximately sidereal rate smoothly and precisely, a new time standard of the vibrating-string type was adopted.[5] Two of these standards are to be used, one for a primary source of constant sidereal time, the other as a controlled time-rate source for the tracking drive as shown in Figure 9. These standards are capable of maintaining an accuracy within less than one tenth of second per day, which is ample for this

Figure 7. Right-ascension drive and computer mechanism with cutaway view of gears above

application. This method of control has been used with success on an automatic drive for the Schmidt Telescope on Palomar Mountain as described by Poitras and Zwicky.[6]

The tracking drive consists of a synchronous motor supplied through an amplifier from the adjusted time source. The rate coil (Figure 9) which changes the frequency of the time standard provides for the automatic tracking drive. By comparing the hour-angle correction Δh from the computer with the difference between the tracking rate T and the sidereal rate T_s, the two angular differences drive a voltage divider controlling the rate coil to bring the tracking rate to the correct value. Thus after the telescope has once been set on a star, the image will remain stationary on the photographic plate without any manipulation by the observer.

For superposed or manual control of the tracking rate, a separate motorized potentiometer is provided which is controlled by the night assistant at the control desk. An ammeter in series with the rate coil is calibrated to read seconds of arc per hour deviation from sidereal rate.

Corrected and superposed rates for the declination-drive unit are supplied by separate small motors which are controlled by Selsyns from the computer and a manual switch from the desk. These motors are supplied through rate integrators to prevent any sudden changes in rate exceeding one-tenth second of arc. The declination rate is indicated at the desk by a Selsyn-driven dial.

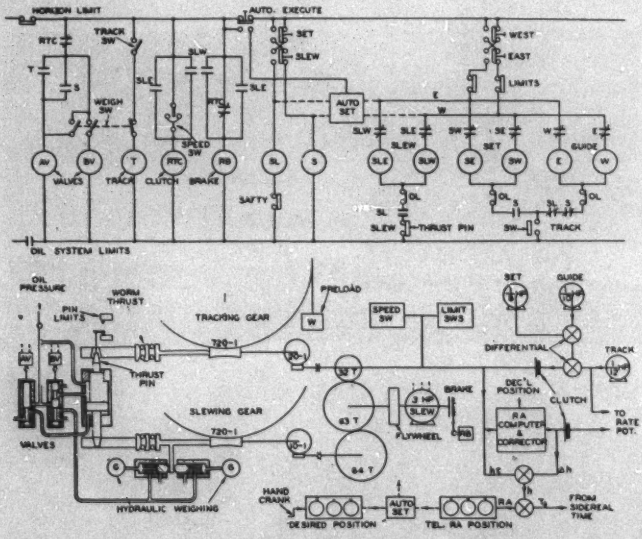

Figure 8. Schematic diagram of right-ascension drive and control system

TELESCOPE-AUXILIARY CONTROLS

One of the more important operating auxiliaries to the telescope is the bearing oil system which feeds oil under pressure to the pads supporting the entire weight of the telescope. The principle of floating the telescope on a film of oil while rotating at slow speed was the practical solution to moving this large weight with a very low coefficient of friction, amounting to less than 4×10^{-4}. Consequently a torque of only about 50 foot-pounds is required to rotate the telescope. It is necessary to have a reliable pumping source and means for maintaining and measuring the oil film clearance at all the pads. At each corner of each pad is a micrometer oil-film switch which will shut off all right-ascension controls if the oil-film thickness becomes less than 0.003 inch; or, by means of indicating lights, the micrometer film switch may be turned to read the actual film thickness to 0.0003 inch. Time relays delay control operations until oil is flowing in all orifices.

Oil-pump systems are also used for the declination gears and for the right ascension gears and machinery. All four of these oil systems are remotely controlled from the desk and fully protected by pressure switches.

Special problems of drive and control have been solved for many of the telescope auxiliaries. Multimotor drives for large pieces of equipment are of two types, one using the parallel operation of two or more d-c shunt-wound motors, and the other using parallel operation of three-phase induction motors with "synchro-tie" or common excited wound-rotor motors to maintain synchronism without mechanical connection. There are two applications of the first method, to the 200-inch mirror cover and the main dome.

The mirror cover is used as a combination iris diaphragm, which can be opened to any desired aperture, and a protecting cover to enclose the mirror when not in use. The 16 cover leaves are driven from two d-c gear-motors through a complete circle shafting around the mirror support ring. The motors are battery-operated, so that the cover can be closed under any conditions of failure of power or failure of one motor.

The main dome, weighing over 1,000 tons, rotates on 32 four-wheel trucks which roll on an accurately ground

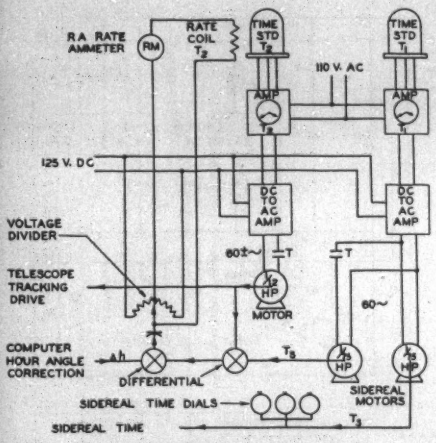

Figure 9. Diagram of right-ascension rate control, time standards for tracking, and sidereal motors

circular track. Two vibration-isolated rubber-tired units, each having two five-horsepower d-c motors, frictionally drive the dome at an automatically controlled, accelerated, and decelerated rate (Figure 10). The dome-rotation controls require operation from five stations and also from the prime-focus hoist platform (one of the elevator motions), from the 60-ton crane cab at the top of the dome, and from the phantom telescope for automatic positioning. A simplified schematic diagram (Figure 11) shows the wiring of dome control for one station and automatic dome control. The modified Ward Leonard system involves the use of a voltage-balance relay to match control voltage 1 to 2 or 1 to 3 with the voltage drop across motor-operated rheostat *RC*. By means of the differential-balance relay *A* and *DA* and motor, the rheostats *RC* and *RF* are made to match the control rheostat, thus fixing the maximum field excitation and hence the speed for the main dome-rotation motors. This rheostat controls the acceleration and deceleration of the dome motors regardless of the speed of moving the control handles. Relays *LS* and *RS* determine direction; A_1 and DA_1, together with the rheostat limits, interlock the operations so that a complete cycle of deceleration is assured after each operation. In order to hold the dome against wind loads, disk brakes on the motor units are set when the motor excitation is nearly zero. The maximum peripheral speed is 80 feet per minute, with about ten seconds required to start and stop the dome. The starting tractive effort of the four vertical gear-motor units under snow-load conditions is 12,000 pounds and the moment of inertia is 15×10^7 pound-feet[3].

To keep the shutter opening of the dome opposite the telescope, an automatic control is provided from the phantom telescope. The position as called for by the phantom is compared with the dome position, and contacts through the dome-motor controls bring the dome to the correct position.

The "synchro-tie" method of drive is applied to the dome shutters. The two shutters roll open between the main arches of the dome. The problem of keeping the top and bottom aligned led to the adoption of this synchro-tie drive which maintains the alignment to 3/16 inch.

Mechanically, the three motors on each shutter are independent. However, the top and bottom are electrically synchronized by the wound-rotor motors (Figure 12) with their rotors connected together, thus keeping the two ends in step within the range of the driving torques. To maintain the proper rotor positions, the excitation to the synchro-tie units is automatically applied before the main motor contactors close. In addition, each shutter is independently driven, introducing the problem of stopping and sealing each half at the center.

Referring to the arrangement of limit switches shown in Figure 12, each side of the center position full voltage and torque are applied to break open the four-inch rubber-tube seals (which may be iced). Subsequent operations after passing limits FV_1 and FV_2 are at reduced voltage because while resealing in both open and closed positions all motors are stalled on the line, and dropped off by time-delay relays. Upon reclosing the shutters, each half may travel at a slightly different speed. The first to arrive in the region between C_1 and C_2 is stopped. The slower shutter, arriving in the region between A_1 and A_2, is controlled by a definite time delay which allows that half to continue and stall, sealing with the first shutter within plus or minus three inches of the true center.

Another auxiliary on the dome that is co-ordinated with the telescope is the wind-screen hoist. This hoist pulls a 32- by 85-foot canvas up in the shutter opening at the zenith angle of the telescope. With this shield, the

Figure 10. Trolley switchboard and dome slip rings with one of two dual drive units used to rotate the 137-foot-diameter dome

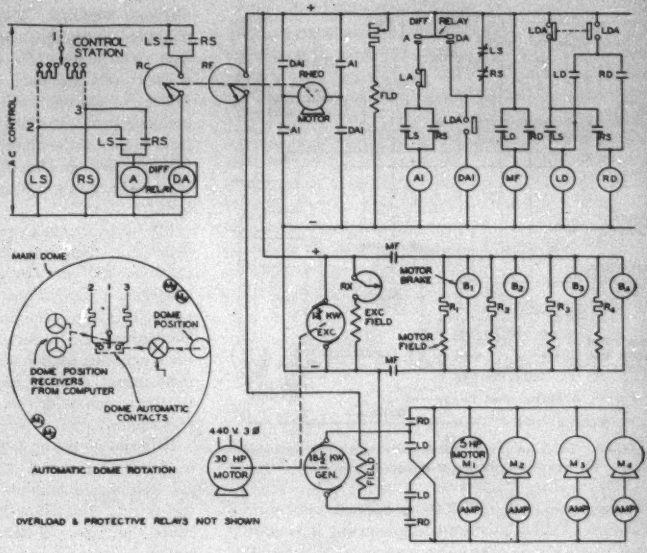

Figure 11. Schematic diagram of dome-rotation circuit showing method of controlling acceleration and speed

telescope is protected against vibrations set up in the mounting by the wind. The method of automatically controlling this hoist from the phantom telescope is shown in Figure 13. The controls were designed to eliminate as many slip-ring connections as possible and to utilize the simplicity of the phantom-telescope mechanism.

The voltage divider R_3 corresponds to the curved section of the dome, and is contacted by the phantom arm corresponding to the telescope tube. Thus the voltage V_3 is proportional to the correct zenith angle of the telescope. A similar voltage divider RW across the same power line, is driven by the hoist drum proportional to the wind-screen travel. Thus the voltage V_w indicates the wind-screen position.

With a simple electronic balance relay the difference in voltage E_1 and E_2 is used to operate the proper contactors to move the wind screen to a balance point corresponding to the position as called for by the phantom. This electronic relay is sensitive to 0.5 volt unbalance, E, from zero to 440 rms volts, which amounts to three inches in wind-screen position. No antihunting device is needed, as the overtravel of the hoist is one third of the relay sensitivity.

CONTROL PANELS AND WIRING

On the main control desk under the north horseshoe, switches and dials are arranged for most convenient use at night. As seen in Figure 14, the vertical rear panel of the desk mounts the preset controls for telescope auxiliaries. On the left are controls for tracking, oil-system pumps, motor generator set, Selsyn excitation, and dome-rotation selector and control master. The center large dials are for sidereal and Pacific Standard time. The right side mounts

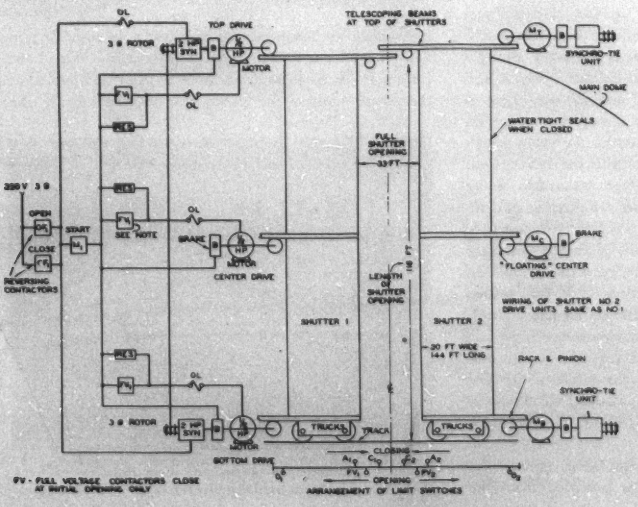

Figure 12. Schematic diagram of dome-shutter drive. Synchro-tie and motor units synchronize top and bottom

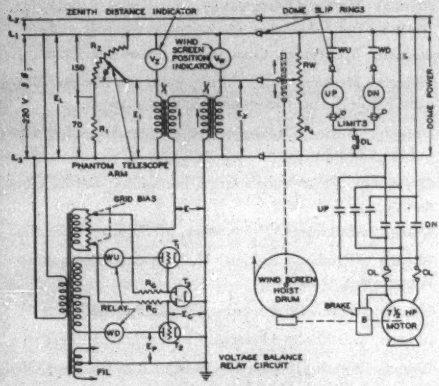

Figure 13. Schematic diagram of automatic wind-screen control operated by phantom-telescope arm

the dial, room, and pilot-light controls and Coudé flat-mirror position selector.

The horizontal section of the desk contains the more important hand-control buttons and presetting hand cranks, together with the setting and position-indicating dials directly above in the center. To the left, within easy reach, are the right-ascension rate, wind-screen, and dome-rotation controls, with zenith distance, wind-screen position, right-ascension rate, and voltmeter instruments above. Similarly, to the right are controls for the 200-inch mirror cover, focus, and declination rate, together with their associated indicator dials above. The controls are operated in the dark, and the dials are opaque with translucent markings, variably illuminated from the rear. Stray light anywhere in the dome has to be kept to an absolute minimum. Also, since operations are at cold night temperatures, all exposed metal parts have been avoided. Desk space is ample for log books, dial telephone, and sound-powered telephone connecting all parts of the telescope and building.

Under normal circumstances, all auxiliary controls on the upper section of the desk will be left preset. Only the main power-control switch need be turned on to bring the telescope into readiness for observing. The night assistant will then proceed to the balcony mirror-control pulpit (see left of Figure 3) at the south from which point most of the telescope moving parts may be viewed.

Energizing the pulpit master circuit locks out control from the main desk and operation of the top row of switches allows any of the auxiliary combinations of mirrors to be swung into place. Indicator lamps of the "dim-bright" type give visual indication of the mechanism moving and also tell when the mechanism and its associated counterweight reach their final and correct positions. Two dials at the bottom center of the pulpit indicate actual and desired tube vertical counterweight position. When the tube is properly balanced, the master switch is reset, restoring controls to the main desk. The night assistant opens the dome shutters and the telescope is then ready for observation work.

Once the desired positions are preset on the desk, "execute" buttons for right ascension and for declination are pressed to bring the telescope to the correct position. These and other operations will be telephonically requested from any of the four observing stations.

Control boxes at each station house the Selsyn and indicator dials, switches for aperture, focus, dome rotation, wind screen, and other functions that may be unique to each station. Hand controllers plug into these stations, providing for north, south, east, and west guiding motions, with transfer button for setting and slewing speeds.

Emergency trip buttons are provided throughout the dome and at all stations to disconnect a-c and d-c power to all equipment that moves on or above the observing floor, including the telescope and the 60-ton crane at the top of the dome.

All these control panels connect by way of wire-armored multiwire cable, and special cables to the mezzanine floor control relay switchboards as indicated in Figure 4. The importance of continuity of electric service for the telescope required the use of high-grade cable capable of trouble-free operation for an exceptionally long time.

POWER SUPPLY

Palomar Mountain as a small community is entirely independent of all outside services. All utilities are provided for 18 buildings, including power and light from a modern Diesel-electric power plant of 300 kw capacity. All observatory power is furnished by three automatically controlled Diesel-driven generator units. Double-bus construction of the conventional switchboard provides for safety, isolation, and special load segregation. Buildings are fed by 15 three-phase 60-cycle underground feeders at 440 volts. One of these feeders terminates at the 200-inch-dome main switchboard. From this board are fed the various building services in addition to the telescope and lighting transformer banks.

Figure 14. Main control desk for telescope

A wide range of illumination problems has been solved for intensities from extremely low levels in the photographic darkrooms, to floodlighting levels required from the glassed-in visitors' gallery. All of the large light cells in the rotating dome, totaling 15 kw, are vented to the shell space and attic to keep all heat out of the 135-foot dome, which is kept at an average night temperature. Passageway, telescope, and stair lights are on throwover circuits, from a-c to d-c. Power, lighting, and control wires feed to balcony panels on the rotating dome through 30 rotating conductor bars on the under side of the balcony. The collector trolleys are part of the disconnect panel (Figure 10).

When complete, the connected load for the 200-inch telescope will be approximately 200 horsepower in motors, 100 kw in heaters, and 50 kw in lights. Thus the power requirements are reasonably small for such a large structure together with all the necessary auxiliaries.

Solutions of the unusual design and control problems encountered on this telescope project have required the close co-operation of engineers and scientists of the California Institute of Technology with many manufacturers who have gladly contributed their services.

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2. The 200-Inch Telescope, **C. S. McDowell.** *Scientific American*, volume 159, August 1938, pages 68–71.

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5. A New Time Standard, **Henry E. Warren.** *AIEE Transactions*, volume 59, 1940 (March section), pages 137–41.

6. Automatic Drive for the Schmidt Telescope on Palomar Mountain, **E. J. Poitras** and **F. Zwicky.** *Scientific Monthly*, volume 52, March 1941, page 286.

The World's Largest Telescopes

200-inch: Astrophysical Observatory of the California Institute of Technology, Palomar Mountain, Calif.

100-inch: (known as the Hooker telescope); Mt. Wilson Observatory of the Carnegie Institution, near Pasadena, Calif.

85-inch: University of Michigan Observatory, Ann Arbor, Mich.

82-inch: McDonald Observatory of the University of Texas, Mt. Locke, Texas.

74-inch: David Dunlap Observatory, University of Toronto, Toronto, Ont.

72-inch: Dominion Astrophysical Observatory, Victoria, B. C.

69-inch: Perkins Observatory of the Ohio Wesleyan University, Delaware, Ohio.

61-inch: Harvard Observatory, Oak Ridge, Cambridge, Mass.

60-inch: Mt. Wilson Observatory, Pasadena, Calif.

60-inch: Harvard Observatory, Southern station (Harvard Kopje), near Bloemfontein, South Africa.

60-inch: National Observatory of the Argentine Republic, Cordoba, Argentina.

48½-inch: Berlin-Babelsburg Observatory, Berlin, Germany.

48-inch: Melbourne Observatory, Melbourne, Australia.

40-inch: (Ritchey-Chrétien) U. S. Naval Observatory, Washington, D. C.

40-inch: Lowell Observatory, Flagstaff, Ariz.

40-inch: Stockholm Observatory, Stockholm, Sweden.

40-inch: Simeis Observatory (a branch of Pulkowo Observatory), Crimea, U.S.S.R.

40-inch: Yerkes Observatory of the University of Chicago, Williams Bay, Wis.

39½-inch: Hamburg University Observatory, Bergedorf, Germany.

39¼-inch: Geneva Observatory, Geneva, Switzerland.

39¼-inch: Meudon Observatory (a branch of the Paris Observatory), Meudon, France.

37½-inch: University of Michigan, Ann Arbor, Mich.

36-inch: (known as Crossley Reflector); Lick Observatory, Mt. Hamilton, Calif.

36-inch: Steward Observatory of the University of Arizona, Tucson, Ariz.

36-inch: Observatory of the Catholic University of Chile, Santiago, Chile (formerly the Chile Station of Lick Observatory).

36-inch: Royal Observatory, Edinburgh, Scotland.

36-inch: Royal Observatory, Greenwich, England.

36-inch: Lick Observatory of the University of California, Mt. Hamilton, Calif.

32½-inch: Meudon Observatory (a branch of the Paris Observatory), Meudon, France.

31½-inch: Astrophysical Observatory, Potsdam, Germany.

30-inch: Pulkowo Observatory, near Leningrad, U.S.S.R.

30-inch: Allegheny Observatory of the University of Pittsburgh, Pittsburgh, Pa.

27-inch: University of Michigan, Southern station at Bloemfontein, South Africa.

27-inch: University Observatory, Vienna, Austria.

26½-inch: Union Observatory, Johannesburg, South Africa.

—*G. Edward Pendray in "Men, Mirrors, and Stars."*

Hybrid Electrical Porcelain Developed

THROUGH research at the Westinghouse Electric and Manufacturing Company's porcelain plant in Derry, Pa., a new porcelain that combines all the advantages of both the wet and dry processes of manufacture recently has been produced on a commercial scale. Intricacy of shape is combined with high dielectric and mechanical strengths at reasonable cost.

Original clay preparation may follow one of two routines. In neither case are the raw materials or their various percentages changed from those commonly used in the production of the best grade of high-voltage porcelain.

The most familiar means of preparing the clay is to add water to a correctly proportioned batch of four raw materials. (See "Manufacture of Electrical Porcelain", R. L. Whitney, ELECTRICAL ENGINEERING, January 1939, pages 7–11.) When this mixture is mechanically agitated, the insoluble raw clays pass into suspension and the resulting "slip" is a smooth, creamy liquid. This liquid is then pumped through a conventional filter press to remove excess water, leaving the clay deposited on the filtering canvasses in the form of round cakes. These filter cakes may be dried further to reduce their moisture content. They are then ground to a fine granular structure. When this granulating operation is complete the clay contains just 17 per cent of moisture. This "dust" is then ready for forming.

A shorter but equally effective process of clay preparation for the new porcelain involves mixture of air-floated raw clays in their dry state, followed by the addition of the proper amount of moisture. The machine used resembles the dry pan of the brick and tile industry, with the difference that the clays are retained in the machine until the whole operation has been completed. Throughout the process the clays are mixed by rotating paddles that direct the materials under heavy steel rollers. The mixing operation is continued while the correct amount of water is added and the whole batch leaves the machine ready for forming.

Clays are delivered to hydraulic or toggle-operated presses capable of developing pressures of 60 to 100 tons. Presses are equipped with dies made of tool steel, each shaped to produce a piece for a particular application, and each specially sealed.

An exact amount of clay is weighed into the die for each piece to be manufactured and then the clay is pressed into the die in much the same manner, mechanically, as in the dry process. There is a fundamental difference, however, the grain size of the clay used, die sealing, and extreme pressure eliminate voids in the pressed piece and produce a wholly continuous structure.

When released from the die the porcelain is completely rigid and can be handled without danger of deformation. Actually it is less susceptible to deformation in handling immediately after forming than a similar piece manufactured by the dry process. Moisture content is so low that finish drying is accomplished in minimum time, most pieces being ready for glazing and firing within 36 hours after pressing. Radiant-heat lamps are particularly satisfactory for this drying process.

After pressing and drying, pieces are ready for the usual glazing and firing. The ware takes the same glaze as ordinary high-voltage ware and is fired at the same temperature and in the same kiln at the same time.

The finished product under the microscope shows the same structure as porcelain manufactured by the wet process. Voids and structural discontinuities typical of dry-process porcelain are absent. It will withstand the normal fusine dye test for porosity as readily as the finest of wet-process material.

Dielectric strength of the new product is not affected even by long immersion in water and is equal to that of the best grade of high-voltage porcelain. Cantilever and tensile strength of prepared samples are slightly better than those qualities in porcelain made by the wet process and resistance to heat shock also is somewhat higher. The latter characteristic indicates that the method used in forming a piece of the "wet-dry" porcelain results in fewer internal stresses that are not completely relieved by drying and firing. Required dimensional tolerances on a given piece are no greater than those for dry-process ware and are less than half the tolerance required for wet-process ware.

As they appear to the naked eye, broken pieces of the hybrid (left) and wet-process (center) porcelain are almost identical in texture. Dry-process porcelain (right) displays a highly porous structure

Protective Lighting for American Industry

DAVIS H. TUCK

Pointing out that protective lighting was invented long before the present war emergency, a lighting engineer outlines in detail practices that are of great present importance

PROTECTIVE lighting is not a new practice grown out of the present war program. It has been in use for the past 25 years and is better known as yard lighting. It has been used by generating plants to prevent raids on the coal pile, in silk mills to prevent theft of valuable merchandise, in automobile factories to prevent theft of storage batteries, tires and other readily saleable parts. Yard lighting has been universally used by steel plants to prevent yard accidents and by many plants as a means of protection of property during strikes. In some industries, such as shipbuilding and structural steel plants and oil refineries, much of the production work is carried on out-of-doors, and yard lighting has been used to facilitate production, storage, and shipping. During war times, theft, fire, strike damage, and interruption of production become "sabotage," and so yard lighting takes on a new name—protective lighting, referring to protection of property—material, facilities, and life and limb. The chief difference is that loss from sabotage is greater and industry can ill afford the loss in such times.

During the past 25 years the lighting industry has developed equipment and methods for its application, so that now protective lighting is on a sound engineering basis, providing adequate results at minimum first cost and operating cost, trouble-free and practical.

In discussing protective lighting, a few basic facts should first be reviewed and acknowledged.

1. Light alone will not afford protection.
2. Guards alone will not afford protection.
3. Both light and guards are needed for protection.
4. Indicating devices to register the presence of persons in the plant property where they should not be are not effective or practical.
5. The saboteur is not the usual criminal moron.
6. Dark locations that are sanctuaries should be avoided.
7. The guard should be stationed in a shack, with a telephone to the captain of the guard and a marine type searchlight of 1,000 watts concentrating size. The guard should not move around from place to place.
8. There should be no glare from *any* direction.
9. The plant should be completely surrounded by a good fence of a type that cannot be climbed.

It is my purpose to describe good practice and omit all wishful thinking and untried or unproved schemes. Good practice is defined as what the best new plants are actually using. Protective lighting, for convenience in layout is divided into three parts: fence lighting; inside-roadway, path, and yard lighting; lighting inside buildings.

FENCE LIGHTING

The purpose of fence lighting is to enable a guard to see anyone loitering outside the fence or attempting to get over it. The requirement is between 0.15 and 0.2 foot-candle.

Figure 1 shows the relation of generated lumens per linear foot between units and foot-candles. For 25-foot mounting height, 10,000-lumen lamps on 150-foot centers will give 66 lumens per linear foot, or 0.25 foot-candle; 6,000 lumen lamps spaced on 150-foot centers will give 40 lumens per linear foot or 0.15 foot-candle; 10,000 lumen lamps on 200-foot centers will give 50 lumens per linear foot or 0.19 foot-candles.

Figure 2 shows the relation between mounting height and glare. At a 25-foot mounting height glare is reduced to the extent that greater mounting heights can cause only a slight further reduction. This mounting

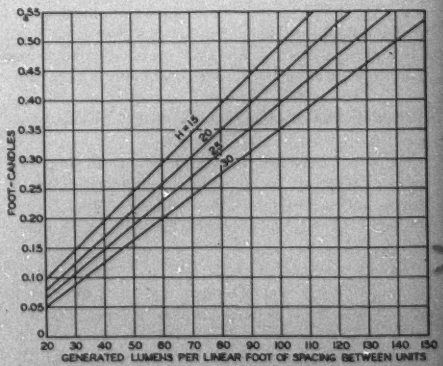

Figure 1. Chart for determining foot-candles at various mounting heights and spacings at which refractors may be used for protective lighting

H—Mounting height of unit above ground

Essential substance of a talk presented before a joint meeting of the AIEE New York Section and the Illuminating Engineering Society, New York, N. Y., February 25, 1941.

Davis H. Tuck is an electrical engineer, Holophane Company, New York, N. Y.

height is also practical for the use of wood or steel poles. The angle of maximum candle power for uniform illumination is

$$\tan^{-1}\frac{1/2 \text{ spacing}}{\text{mounting height}}$$

For example, when the spacing on centers is 200 feet and the mounting height 25 feet, the angle of maximum candle power should be set for

$$\tan^{-1}(100/25) = 76°$$

The angle of maximum candle power from a refractor is adjusted by raising or lowering the lamp in the refractor. Raising the lamp decreases the angle and lowering the lamp increases it.

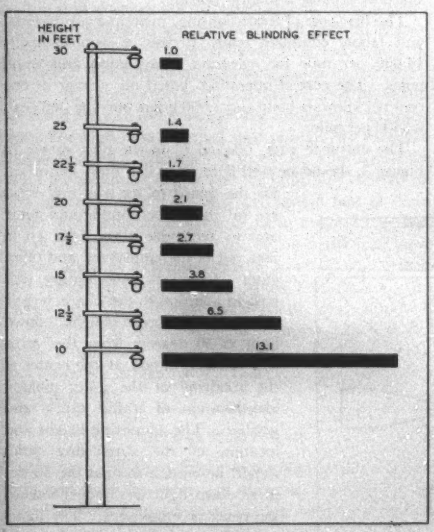

Figure 2. Relative blinding effects of glare from lamps at different mounting heights

Candle power assumed constant

Figure 3 shows a plan of a typical industrial plant on which fence lighting and yard lighting have been laid out. The fence-lighting units (see also Figure 4) are on approximately 200-foot centers and are mounted 25 feet above the ground, with 10,000-lumen 20-ampere series lamps. The lumens per linear foot of fence are 10,000/200 = 50. From Figure 1 it will be seen that the illumination will be 0.19 foot-candle (7.5 times full moonlight, which is 0.025 foot-candle). The angle of maximum candle power is set at

$$\tan^{-1}(100/25) = 76°$$

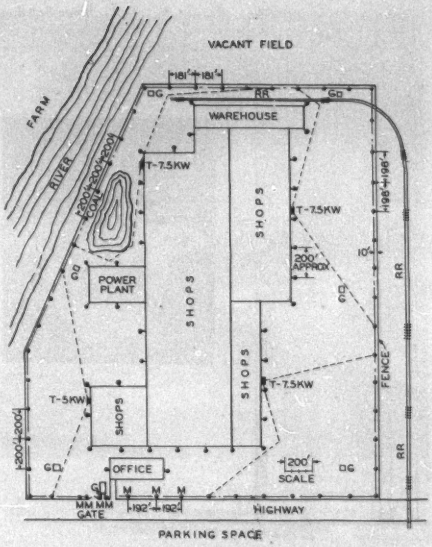

Figure 3. Plan of typical industrial plant, showing fence lighting, gate lighting, and yard lighting

G indicates location of guard's shack; T, constant-current transformer; M, lamps on multiple supply

The type of horizontal light distribution will depend to a large extent on local conditions such as type of guard duty and usage of ground area between fence and buildings. Good practice is to use an asymmetrical distribution of light, with most light concentrated along the fence. Figure 5c shows the vertical- and horizontal-candle power distribution curve that would be used for all locations along the fence except at the corners, where a symmetrical distribution as shown in Figure 5e would be used.

Either an overhead or an underground system of wiring could be used. The circuits would be divided into four parts and each circuit supplied by a constant-current 6.6-ampere transformer with 2,400-volt 60-cycle primary. An *IL*-type insulating transformer would be used for each unit to convert the 6.6-ampere circuit to one of 20 amperes. Such a transformer also has the advantage of increasing safety by keeping high voltage off the fixture.

The entire circuit could be fed from a single constant current transformer if desired. Instead of 20-ampere 10,000-lumen lamps, 6.6-ampere 6,000-lumen lamps could be used and the insulating transformers omitted. In this case, the spacing of units would be reduced to 150 feet. The illumination would be 0.15 foot-candle and the angle of maximum candle power would be

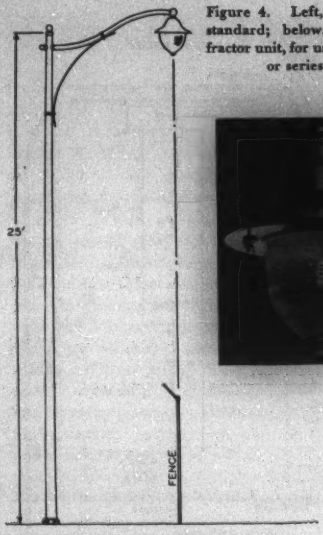

Figure 4. Left, fence-lighting standard; below, complete refractor unit, for use with multiple or series lamps

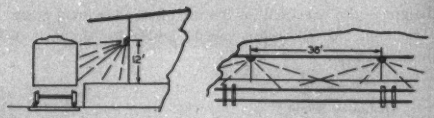

Figure 6. Installation of shipping-platform lighting

70 degrees. An advantage of the *IL*-transformer construction is that a disconnecting hanger can be used for lamp replacement and maintenance. The poles should be located either four feet inside the fence line, with a four-foot bracket used to bring the light directly over the fence, or back inside the fence line at least 10 feet to prevent the light from striking the fence at an angle so sharp as to cause a shadow outside.

The first cost of fence lighting, including all material and labor, complete ready to use, is approximately $4,000 per mile for overhead construction and wood poles. The cost of operation, based on current at one cent per kilowatt-hour and 3,000 hours burning per year, is $400 per mile.

The entrance gate, marked *G* on the plan shown in Figure 3, should be well lighted, as it is most important for the guard to see who and what are on the trucks coming and going and to recognize those who go in and out of the employees' and office gate. A typical gate-lighting unit has, in addition to the characteristic refractor-wide spread of light, a down light at 30 degrees from the vertical, which is aimed at the center of the roadway at the gate, making identification of traffic quick and positive. The mounting height and location of the supporting poles should be chosen so that the 30 degrees down light is directed toward the truck or employees. The lights near the entrance, marked *M* in Figure 3, are on a separate multiple circuit for additional reliability. Many plants are providing a Diesel engine-generator set for emergency use on the protective-lighting system.

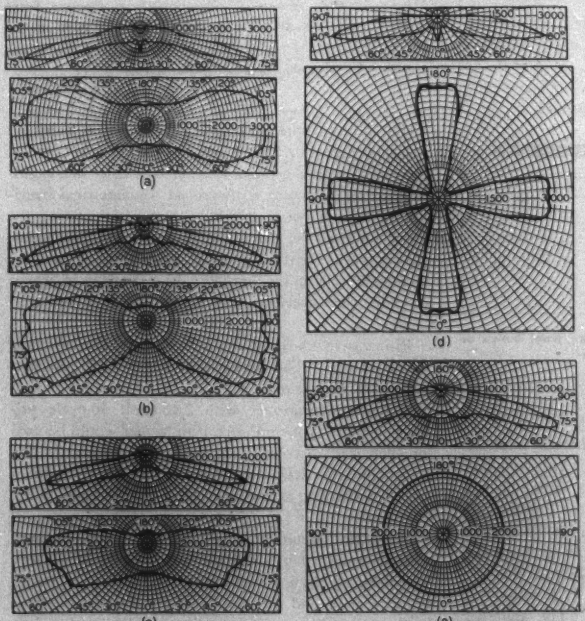

Figure 5. Vertical and horizontal candle-power-distribution curves of various types of refractors used with multiple or series lamps for protective lighting

INSIDE ROADWAY, PATH, AND YARD LIGHTING

Roadways inside the plant are lighted in exactly the same manner as is the fence. Walk paths use small 200-watt multiple-circuit refractors mounted on poles 18 feet above the ground and spaced on 100-foot centers to give 0.18 foot-candles. For yard lighting, refractor

units having a 180-degree lateral distribution are mounted on building walls. The units at building corners should have 270 degrees of horizontal distribution. In locations where no buildings are available for mounting, poles should be used, with a 360-degree or symmetrical distribution (Figure 5e). The units shown mounted on the buildings in Figure 3 compose the yard-lighting system. It is common practice to use multiple circuits for yard lighting, as the supply can be obtained from convenient building circuits.

PROTECTIVE LIGHTING INSIDE BUILDINGS

Protective lighting inside buildings is usually called night lighting or watchman's circuit lighting. These lights should be left burning all night when there is not a night shift working, not turned on and off by the watchman as he makes his rounds. A low but uniform illumination is required. Approximately 0.25 foot-candle is sufficient. For low bays, 200-watt lamps in refractors spaced on approximately 70-foot centers and mounted approximately 12 feet from the floor represent good practice. For high bays a spread type of high-bay reflector should be used. The spacing should be approximately twice the mounting height and the lamp size selected to give approximately 1/25-watt per square foot of floor area. For instance, a 300-watt lamp mounted 40 feet above the floor in a spread-type high-bay reflector having an angle of maximum candle power at 45 degrees and spaced on 80-foot centers would be sufficient. In cases where 400-watt mercury lamps are used, stand-by of incandescent illumination of intensity sufficient for safety is desirable. In such cases a part of the incandescent-lamp system could constitute the protective lighting system.

SHIPPING PLATFORMS

Although shipping-platform lighting is part of the work-light system of the plant it is desirable to include it in this discussion on protective lighting because shipping

Figure 7. Properly installed shipping-platform lighting provides good illumination not only along the platform itself but into the car or truck being loaded

platforms are vulnerable places. Men who are not plant employees are often present on trucks or in cars, and large quantities of finished products are collected there for shipment. Figure 6 shows a plan and elevation of a typical shipping platform. The lights are mounted vertically on the side wall, approximately 12 feet above the platform, and spaced on approximately 36-foot centers, with 200-watt lamps used. The illumination is approximately two foot-candles. Advantages of this type of shipping-platform lighting are lack of mechanical interference and good working light on the platform and into the car or truck. These lights should be burned all night along with the protective-lighting system.

Figure 8. Protective lighting at the Oil Gear Machine Company, Milwaukee, Wis., uses refractors with 500-watt multiple lamps mounted 22 feet above grade and spaced irregularly to conform with property line

Heaviside's Direct Operational Calculus

J. B. RUSSELL
MEMBER AIEE

During the winter of 1940–41 the basic science group of the AIEE New York Section held a symposium at Columbia University on "Advanced Methods of Mathematical Analysis as Applied to Electrical Engineering." The members attending those lectures found them so interesting that the speakers were asked to prepare articles on their respective topics in order to make the material available to the entire Institute membership through publication in Electrical Engineering. This article is the first of a series of five. Future articles will deal with integration in the complex plane, Laplace transforms, Fourier integrals, and traveling waves on transmission lines.

The purpose of the lectures was to present to engineers condensed and simplified versions of the topics under discussion, and the lectures are to be published in essentially the form in which they were originally delivered. The material involved is not new and may be found in more rigorous and complete form in the textbooks and papers noted in the reference lists accompanying the articles.

It is possible that these articles might serve as background material for round-table discussions on advanced mathematics. A consolidated pamphlet reprint of the series will be available for this purpose after the last article has appeared in Electrical Engineering.

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OPERATIONAL CALCULUS is a very powerful tool for solving the differential equations of engineering. This article discusses some of the basic principles of Heaviside's direct operational calculus and how they can be applied to the solution of engineering problems. No attempt will be made to prove the various expressions that are to be used or to cover completely all the points of interest. The necessary justifications can be derived from the material to be presented in subsequent articles of this series.

OPERATORS

The operational idea is not new. One of the most familiar operators is the trigonometric sine operator. Its operation is expressed by the equation

$$y = \sin(x) \tag{1}$$

The function being operated on is x, which is called the operand. The operator is expressed by the symbol sin ( ), and when it is applied to x serves to transform the function x into the function y. Usually there also is an inverse operator which, when applied to y in equation 1, transforms y back into the function x. For this case the inverse operator is expressed by the symbol $\sin^{-1}$ ( ) and when applied to equation 1 gives

$$\sin^{-1}(y) = \sin^{-1}(\sin x) = x \tag{2}$$

There are a number of other equally familiar operators, such as those expressed by the following symbols: cos ( ), ( )^2, d/dt( ), and $\int_0^t$( )dt.

The last two of these operators are the ones which form the basis for Heaviside's operational calculus. They are commonly expressed by the symbols p( ) and $1/p$( ), respectively. The independent variable shown is time t and the operations are to be performed on functions of time. However, the operational process is general and may be applied to functions of other independent variables. Operations by p and $1/p$ on a time function are expressed by the following equations:

$$\left.\begin{aligned} pf(t) &= \frac{d}{dt} f(t) \\ \frac{1}{p} f(t) &= \int_0^t f(t)\,dt \end{aligned}\right\} \tag{3}$$

The operators of equations 3 are the inverse of each other. That is, either operation on a function of time followed by the second operation on the result leaves the original function unchanged. This is expressed by the equation

$$\left.\begin{aligned} p\left[\frac{1}{p} f(t)\right] &= \frac{d}{dt}\left[\int_0^t f(t)\,dt\right] = f(t) \\ \frac{1}{p}\left[pf(t)\right] &= \int_0^t \frac{d}{dt} f(t)\,dt = f(t) \end{aligned}\right\} \tag{4}$$

In order for these equations to be valid even when $f(0) \neq 0$ the integration indicated must start not exactly at $t=0$ but at some very small interval of time before $t=0$.

The time functions which are the operands of the Heaviside operators have zero value for negative values of the independent time variable t. One such function is Heaviside's unit function, which is expressed by the

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symbol **1** or $\mathbf{1}(t)$. It has the value zero for negative values of time and the value plus one for positive values of time and thus has a discontinuity at $t=0$. This can be expressed as follows

$$\begin{aligned}&\mathbf{1}=0 \text{ for } t<0\\&\mathbf{1}=1 \text{ for } t>0\end{aligned} \qquad (5)$$

Multiplying any time function by **1** produces zero for negative values of time and leaves the function unchanged for positive values of time. Thus the unit function is considered to be a factor of all the operands and is itself the simplest one.

OPERATIONAL EQUATIONS

The basic operational equation is

$$Y(p)\mathbf{1}=f(t)\mathbf{1} \qquad (6)$$

$Y(p)$ is an algebraic function of the operator p and when operating on the time function **1** transforms it into the time function $f(t)\mathbf{1}$. Equation 6 is entirely symbolic and its interpretation must be justified by classical mathematics. The relations expressed "operationally" by equation 6 are also expressed by

$$\frac{Y(p)}{p}=\int_0^\infty \epsilon^{-pt}f(t)dt \qquad (7)$$

The integral is known as the Laplacian transform of $f(t)$ and serves to transform the t-function $f(t)$ into the p-function $Y(p)/p$. In equation 7 the variable p is taken as an algebraic quantity and has no operational properties. There is an inverse transformation to (7) which serves to transform the function $Y(p)/p$ back into $f(t)$. This inverse transformation and the direct transformation expressed by equation 7 will be discussed in detail in a subsequent article. Expression 7 is a classical mathematical equation which may be used to justify the interpretation of the operational equation 6.

The simplest operational equation is

$$\frac{1}{p}\mathbf{1}=\int_0^t \mathbf{1}dt=t\mathbf{1} \qquad (8)$$

This operation by $1/p$ may be repeated to give

$$\frac{1}{p}\left(\frac{1}{p}\mathbf{1}\right)=\frac{1}{p^2}\mathbf{1}=\frac{1}{p}t\mathbf{1}=\int_0^t t\,dt=\frac{t^2}{2}\mathbf{1} \qquad (9)$$

and

$$\frac{1}{p^n}\mathbf{1}=\frac{t^n}{n!}\mathbf{1} \qquad (10)$$

Operating on equation 10 by p^m would give

$$p^m\left(\frac{t^n}{n!}\mathbf{1}\right)=\frac{p^m}{p^n}\mathbf{1}=\frac{1}{p^{n-m}}\mathbf{1}=\frac{d^m}{dt^m}\left(\frac{t^n}{n!}\mathbf{1}\right)=\frac{t^{n-m}}{(n-m)!}\mathbf{1} \qquad (11)$$

assuming that $m<n$. Such repeated operations by p or $1/p$ are quite easy to understand. Difficulty arises only when $n<m$, and this will be discussed later.

More complicated operations on the unit function may be interpreted in terms of equations 10 and 11. Consider the operational equation

$$\frac{p}{p+a}\mathbf{1}=f(t)\mathbf{1} \qquad (12)$$

The result of such an operation is not immediately apparent but may be made so by expressing the operator in terms of a power series in the operator $1/p$. Each term of this series may then be evaluated by equation 10. Carrying this process out gives

$$\left.\begin{aligned}\frac{p}{p+a}\mathbf{1}=\frac{1}{1+\frac{a}{p}}\mathbf{1}&=\left(1-\frac{a}{p}+\frac{a^2}{p^2}-\frac{a^3}{p^3}+\frac{a^4}{p^4}\cdots\right)\mathbf{1}\\&=\left(1-at+\frac{a^2t^2}{2!}-\frac{a^3t^3}{3!}+\frac{a^4t^4}{4!}\cdots\right)\mathbf{1}\end{aligned}\right\} \qquad (13)$$

and thus

$$\frac{p}{p+a}\mathbf{1}=\epsilon^{-at}\mathbf{1} \qquad (14)$$

Equation 14 is valid for both positive and negative values of a.

Another operational equation may be derived by operating on equation 14 by $1/p$. This gives

$$\frac{1}{p}\left(\frac{p}{p+a}\right)\mathbf{1}=\frac{1}{p+a}\mathbf{1}=\int_0^t \epsilon^{-at}dt$$

Thus

$$\frac{1}{p+a}\mathbf{1}=\frac{1}{a}(1-\epsilon^{-at})\mathbf{1} \qquad (15)$$

Similarly equation 14 may be operated on by p to give

$$p\left(\frac{p}{p+a}\right)\mathbf{1}=\frac{p^2}{p+a}\mathbf{1}=\frac{d}{dt}(\epsilon^{-at}\mathbf{1}) \qquad (16)$$

Since **1** is a time function, the result of the differentiation is

$$\frac{p^2}{p+a}\mathbf{1}=-a\epsilon^{-at}\mathbf{1}+\epsilon^{-at}\frac{d}{dt}\mathbf{1} \qquad (17)$$

This same result may be obtained by rewriting the operator as follows

$$\frac{p^2}{p+a}\mathbf{1}=\left(p-\frac{ap}{p+a}\right)\mathbf{1}=p\mathbf{1}-a\epsilon^{-at}\mathbf{1} \qquad (18)$$

The term $p\mathbf{1}$ is identical to $\epsilon^{-at}\frac{d}{dt}\mathbf{1}$, since the derivative of **1** is zero for all values of time except $t=0$, where it is infinite and $\epsilon^{-at}=\mathbf{1}$. The operator of equation 17 is called an impulse operator because it produces the time function $p\mathbf{1}$, which is called an impulse. This results from differentiating a time function having a discontinuity at $t=0$, such as **1** or $\epsilon^{-at}\mathbf{1}$. Whenever the numerator of a rational algebraic operator, such as is in equation 17, is higher in degree than the denominator, the corresponding time function will contain an impulse. In equations 4 if $f(0)\neq 0$ then differentiating $f(t)$ pro-

duces an impulse function as well as the usual derivative function. In order for the integration to be the exact inverse operation of the differentiation it must include the integral of the impulse function. Since the impulse occurs at $t=0$ the integration must start before $t=0$.

HEAVISIDE'S EXPANSION THEOREM

When the operator $Y(p)$ in equation 6 is in the form of a rational fraction with no multiple roots in the denominator, it may be expressed as the sum of partial fractions, each one of which has the form given in equation 14. Consider for example the operational equation

$$\frac{p}{(p+a)\ (p+b)}\,1=f(t)1 \tag{19}$$

The operator may be expressed as the sum of partial fractions to give

$$\frac{p}{(p+a)\ (p+b)}\,1=\left(\frac{Ap}{p+a}+\frac{Bp}{p+b}+C\right)1 \tag{20}$$

where

$$A=\frac{1}{b-a}\qquad B=\frac{1}{a-b}\qquad C=0 \tag{21}$$

By means of equation 14 the component operations in equation 20 may be evaluated and thus equation 19 becomes

$$\frac{p}{(p+a)(p+b)}\,1=\frac{1}{b-a}\,\frac{p}{p+a}\,1+\frac{1}{a-b}\,\frac{p}{p+b}\,1=\frac{\epsilon^{-at}-\epsilon^{-bt}}{b-a}\,1 \tag{22}$$

The general rule for applying the partial-fraction expansion process to the evaluation of the operational equation 6 is known as Heaviside's expansion theorem. It may be derived directly by the use of Laplacian transforms, which are the subject of a future article in this series.

Indicating $Y(p)$ as a rational fraction we have

$$Y(p)1=\frac{m(p)}{\Delta(p)}\,1=f(t)1 \tag{23}$$

where $m(p)$ and $\Delta(p)$ are polynomials in p. By expanding $Y(p)$ in partial fractions, and then using equation 14 for each such fraction, there results

$$\frac{m(p)}{\Delta(p)}\,1=\frac{m(0)}{\Delta(0)}+\sum_{\kappa=1}^{\kappa=n}\frac{m(\lambda_\kappa)}{\lambda_\kappa\Delta'(\lambda_\kappa)}\,\epsilon^{\lambda_\kappa t}1 \tag{24}$$

where λ_κ is one of the n roots of $\Delta(\lambda_\kappa)=0=Z(\lambda_\kappa)$, and $\Delta'(\lambda_\kappa)$ is the derivative of $\Delta(p)$ with respect to p at the point $p=\lambda_\kappa$. Equation 24 may be expressed also in several other forms.

A more general form of the expansion theorem may be written when the operand is not **1** but $\epsilon^{at}1$. This general form is

$$Y(p)\epsilon^{at}1=\frac{m(p)}{\Delta(p)}\,\epsilon^{at}1=\frac{m(a)}{\Delta(a)}\,\epsilon^{at}1+\sum_{\kappa=1}^{\kappa=n}\frac{m(\lambda_\kappa)}{(\lambda_\kappa-a)\Delta'(\lambda_\kappa)}\,\epsilon^{\lambda_\kappa t}1 \tag{25}$$

It is very useful in solving problems involving alternating voltage, since $\cos\omega t$ and $\sin\omega t$ may be expressed as the real and imaginary parts, respectively, of the complex time function $\epsilon^{j\omega t}$.

THE SUPERPOSITION THEOREM

The superposition theorem describes a method for solving an operational equation which expresses an operation on a general form of operand such as $f(t)1$. The result is given by

$$Y_1(p)f_2(t)1=\frac{d}{dt}\int_0^t f_1(\lambda)f_2(t-\lambda)\,d\lambda=\frac{d}{dt}\int_0^t f_1(t-\lambda)f_2(\lambda)\,d\lambda \tag{26}$$

where

$$Y_1(p)1=f_1(t)1 \tag{27}$$

Equation 26 expresses the operation of $Y_1(p)$ on the time function $f_2(t)1$ in terms of $f_2(t)1$ and the operation of $Y_1(p)$ on **1** alone which by equation 27 gives $f_1(t)1$. This means that if the transient response of an electric network due to a voltage **1** is known, the transient response of the network to any other voltage may be determined by equation 26.

Since $f_2(t)1$ may be considered to be the result of an operation on **1** by an operator $Y_2(p)$, equation 26 may be written in several forms. These are

$$Y_1(p)f_2(t)1=Y_1(p)Y_2(p)1=Y_2(p)Y_1(p)1=Y_2(p)f_1(t)1=f(t) \tag{28}$$

where

$$\left.\begin{aligned} &Y_1(p)1=f_1(t)1 && Y_2(p)1=f_2(t)1\\ &f(t)=\frac{d}{dt}\int_0^t f_1(\lambda)f_2(t-\lambda)\,d\lambda=\frac{d}{dt}\int_0^t f_1(t-\lambda)f_2(\lambda)\,d\lambda \end{aligned}\right\} \tag{29}$$

In equation 28 the order of the operators $Y_1(p)$ and $Y_2(p)$ has been reversed, or commuted, but the order of the operators with respect to the time functions has been carefully maintained. The operators themselves follow all the rules of common algebra, but they must be kept in their proper relation with respect to the time functions on which they operate. Equation 28 can be used to determine the result of two successive operations on **1**, or to express it differently, to determine the result of a single operation where the operator $Y(p)$ may be expressed as the product of two factors $Y_1(p)$ and $Y_2(p)$.

A slightly different form of equation 28, known as Borel's theorem, may be derived by operating on that equation by $1/p$. The result is

$$\frac{1}{p}Y_1(p)Y_2(p)1=\int_0^t f_1(\lambda)f_2(t-\lambda)\,d\lambda=\int_0^t f_1(t-\lambda)f_2(\lambda)\,d\lambda \tag{30}$$

where the various symbols have the meaning given in equation 29. The main advantage of the form given in equation 30 is to avoid the differentiation expressed in equation 28.

TRANSFORMATION OF OPERATORS

The work of solving an operational equation, such as equation 6 often may be facilitated by transforming the operator in various ways, and transforming the resulting

time function in a corresponding way. Three such transformations have been given in equations 22, 26, and 28. Another set of useful transformations are given by the Heaviside shifting theorems. They are used to shift an exponential time function from one side of the operator to the other, and are

$$\Upsilon(p)f(t)\epsilon^{-at}1=\epsilon^{-at}\Upsilon(p-a)f(t)1 \tag{31}$$

$$\Upsilon(p)1=\epsilon^{-at}\frac{p}{p-a}\Upsilon(p-a)1 \tag{32}$$

$$\epsilon^{-at}\Upsilon(p)1=\frac{p}{p+a}\Upsilon(p+a)1 \tag{33}$$

A few other useful transformations of equation 6 are

$$\Upsilon\left(\frac{p}{a}\right)1=f(at)1 \tag{34}$$

$$-p\frac{d}{dp}\left[\frac{\Upsilon(p)}{p}\right]1=tf(t)1 \tag{35}$$

$$\left[p\int_p^\infty\frac{\Upsilon(p)}{p}\,dp\right]1=\frac{f(t)}{t}1 \tag{36}$$

The time functions produced by various operations on 1 have definite initial values, that is, value for $t=0$. As has already been explained, these time functions are zero for t negative. In physical problems the initial values given by the Heaviside operators acting on 1 are those corresponding to a physical system in equilibrium before the disturbing force is applied.

These initial values of equation 6 are given by the relations

$$f(0)=\Upsilon(\infty) \tag{37}$$

$$f'(0)=[p\Upsilon(p)-pf(0)]_{p=\infty} \tag{38}$$

If equation 37 is used to determine the initial value of $df(t)/dt=f'(t)$ and $f(0)\neq 0$ the result will be infinity. This is illustrated by equation 17. However, it is usually necessary to know the initial value of $f'(t)$ after the impulse due to the discontinuity in $f(t)$ has been removed. This is the result expressed by equation 38. If the finite initial value of higher-order derivatives of $f(t)$ is desired, the transformation, equation 38, may be repeated as many times as necessary.

Another limiting value of equation 6 is of interest. This is the final value of $f(t)$ and is given by

$$f(\infty)=\Upsilon(0) \tag{39}$$

IRRATIONAL OPERATORS

A number of operators that are not rational arise in the solution of physical problems. Some of these may be interpreted by the series-expansion method. In this case the irrational operator is expressed in a series of $1/p^n$, each term of which may be evaluated by equation 10. This process applied to a rational operator is illustrated in equation 14. When the series-expansion method cannot be used, the solution to the operational equation 6 must be found by solving the corresponding integral equation 7. This is the Laplacian transform method.

One illustration of the series-expansion method applied to an irrational operator is:

$$\left.\begin{aligned}\frac{p}{\sqrt{p^2+a^2}}1&=p\left(\frac{1}{p}-\frac{a^2}{2p^3}+\frac{3}{2^2}\frac{a^4}{p^5}-\frac{5}{2^4}\frac{a^6}{b^7}+\cdots\right)1\\&=\left(1-\frac{a^2}{2p^2}+\frac{3}{2^2}\frac{a^4}{p^4}-\frac{5}{2^4}\frac{a^6}{p^6}+\cdots\right)1\\&=\left(1-\frac{a^2t^2}{2^2}+\frac{a^4t^4}{2^24^2}-\frac{a^6t^6}{2^24^26^2}+\cdots\right)1\\&=J_0(at)1\end{aligned}\right\} \tag{40}$$

The power series given in equation 40 is common enough to have a special name and symbol and is tabulated in great detail. $J_0(at)$ is known as a Bessel function of the first kind and zero order.

Another example of the series-expansion method is given by the Heaviside transfer operator ϵ^{-hp}. When applied to a time function $f(t)$ there results

$$\left.\begin{aligned}\epsilon^{-hp}f(t)&=\left(1-hp+\frac{h^2p^2}{2!}-\frac{h^3p^3}{3!}+\cdots\right)f(t)\\&=f(t)-h\frac{d}{dt}f(t)+\frac{h^2}{2!}\frac{d^2}{dt^2}f(t)-\frac{h^3}{3!}\frac{d^3}{dt^3}f(t)+\cdots\\&=f(t-h)\end{aligned}\right\} \tag{41}$$

This last result is obtained by noting that the series in the successive derivatives of $f(t)$ is a Taylor series expansion of $f(t-h)$.

An example of an irrational operator that must be interpreted by means of equation 7 is

$$p^{1/2}1=\frac{1}{(\pi t)^{1/2}}1 \tag{42}$$

ILLUSTRATIONS

1. Consider the following differential equation

$$\frac{d^2y}{dt^2}+7\frac{dy}{dt}+10y=\epsilon^{-10t}1 \tag{43}$$

This can be written operationally as

$$\left.\begin{aligned}(p^2+7p+10)y&=\epsilon^{-10t}1\\(p+2)(p+5)y&=\epsilon^{-10t}1\end{aligned}\right\} \tag{44}$$

Solving for y as though p were an algebraic quantity gives

$$y(t)=\frac{1}{(p+2)(p+5)}\epsilon^{-10t}1 \tag{45}$$

It is very important to write the operator before the time function to indicate correctly the operation. By means of equation 14 the exponential time function may be expressed in terms of its operator to give

$$y(t)=\frac{p}{(p+2)(p+5)(p+10)}1 \tag{46}$$

This operational equation may be solved by the expansion theorem given in equation 24. The result is

$$y(t) = \frac{-2}{-2(-2+5)(-2+10)}\epsilon^{-2t}1 + \frac{-5}{-5(-5+2)(-5+10)}\epsilon^{-5t}1 + \frac{-10}{-10(-10+2)(-10+5)}\epsilon^{-10t}1$$

$$y(t) = \frac{1}{24}\epsilon^{-2t}1 - \frac{1}{15}\epsilon^{-5t}1 + \frac{1}{40}\epsilon^{-10t}1 \tag{47}$$

This result may also be obtained by the use of equation 25.

By applying equation 38 to equation 46, the initial valuesof $y(t)$ and its derivatives may be found. They are

$$\left.\begin{aligned} y(0) &= \left[\frac{p}{(p+2)(p+5)(p+10)}\right]_{p=\infty} = 0 \\ y'(0) &= \left[\frac{p^2}{(p+2)(p+5)(p+10)}\right]_{p=\infty} = 0 \\ y''(0) &= \left[\frac{p^3}{(p+2)(p+5)(p+10)}\right]_{p=\infty} = 1 \\ y'''(0) &= \left[\frac{p^4}{(p+2)(p+5)(p+10)} - p\right]_{p=\infty} = \frac{1}{17} \end{aligned}\right\} \tag{48}$$

2. A circuit consisting of an inductance of 1 henry and a resistance of 100 ohms in series has applied to it the voltage $\epsilon^{-100t}1$. There is initially no current in the inductance. The differential equation for this circuit is

$$\frac{di}{dt} + 100i = \epsilon^{-100t}1 = (p+100)i = \epsilon^{-100t}1 \tag{49}$$

The operational equation for $i(t)$ is thus

$$i(t) = \frac{1}{p+100}\epsilon^{-100t}1 = \frac{p}{(p+100)^2}1 \tag{50}$$

Since the denominator of the operator acting on 1 has two equal roots at $p=-100$, the expansion theorem does not apply directly. Several other methods may be used to find the solution. The simplest is to apply equation 31. This gives

$$i(t) = \frac{1}{p+100}\epsilon^{-100t}1 = \epsilon^{-100t}\frac{1}{p-100+100}1 = \epsilon^{-100t}\frac{1}{p}1 = \epsilon^{-100t}t1 \tag{51}$$

Another method is to use the superposition theorem given by equation 28. In this case

$$f_1(t) = \frac{1}{p+100}1 = \frac{1}{100}(1-\epsilon^{-100t})1 \tag{52}$$

$$f_2(t) = \epsilon^{-100t}1$$

and

$$\left.\begin{aligned} i(t) &= \frac{d}{dt}\int_0^t \frac{1}{100}(1-\epsilon^{-100\lambda})\epsilon^{-100(t-\lambda)}\,d\lambda \\ &= \frac{1}{100}\frac{d}{dt}\left[\epsilon^{-100t}\int_0^t (\epsilon^{100\lambda}-1)d\lambda\right] \\ &= \frac{1}{100}\frac{d}{dt}\left[\epsilon^{-100t}\left(\frac{\epsilon^{100t}}{100} - \frac{1}{100} - t\right)\right] \\ &= \frac{1}{100}\frac{d}{dt}\left[\frac{1}{100} - \frac{\epsilon^{-100t}}{100} - t\epsilon^{-100t}\right] = t\epsilon^{-100t}1 \end{aligned}\right\} \tag{53}$$

Equation 50 also may be solved by the use of equation 36. The original equation is

$$\frac{p}{(p+100)^2}1 = i(t)$$

Applying equation 36 gives

$$\left.\begin{aligned} \left[p\int_p^\infty \frac{dp}{(p+100)^2}\right]1 &= \frac{i(t)}{t} \\ -\left[p\left(\frac{-1}{p+100}\right)_{p=\infty}^{p=0}\right]1 &= \frac{p}{p+100}1 = \epsilon^{-100t}1 \end{aligned}\right\} \tag{54}$$

$$i(t) = t\epsilon^{-100t}1$$

3. An operational equation that may arise in the solution of a certain electric transmission-line problem is

$$\sqrt{p+a}\,\epsilon^{-at}1 = f(t) \tag{55}$$

This may be easily evaluated by means of equations 31 and 42. Thus

$$\left.\begin{aligned} f(t) &= \epsilon^{-at}\sqrt{p-a+a}\,1 = \epsilon^{-at}\sqrt{p}\,1 \\ &= \epsilon^{-at}\frac{1}{\sqrt{\pi t}}1 \end{aligned}\right\} \tag{56}$$

The series-expansion method also may be illustrated by this problem. Using equation 14, there results

$$f(t) = \sqrt{p+a}\,\epsilon^{-at}1 = \frac{p}{\sqrt{p+a}}1 \tag{57}$$

By the binomial expansion theorem this becomes

$$\left.\begin{aligned} \frac{p}{\sqrt{p+a}}1 &= p\left(p^{-1/2} - \frac{1}{2}p^{-3/2}a + \frac{1}{2}\cdot\frac{3}{2}\cdot\frac{1}{2!}p^{-5/2}a^2 - \frac{1}{2}\cdot\frac{3}{2}\cdot\frac{5}{2}\cdot\frac{1}{3!}p^{-7/2}a^3 + \cdots\right)1 \\ &= \left(1 - \frac{1}{2}\frac{a}{p} + \frac{1}{2}\cdot\frac{3}{2}\cdot\frac{1}{2!}\frac{a^2}{p^2} - \frac{1}{2}\cdot\frac{3}{2}\cdot\frac{5}{2}\cdot\frac{1}{3!}\frac{a^3}{p^3} + \cdots\right)p^{1/2}1 \end{aligned}\right\} \tag{58}$$

Since from equation 42,

$$p^{1/2}1 = \frac{1}{(\pi t)^{1/2}}$$

and from equation 3 the operation $1/p$ is the integral from 0 to t, equation 58 may be written as

$$\left.\begin{aligned} f(t) &= \frac{1}{\sqrt{\pi}}\left(\frac{1}{t^{1/2}} - at^{1/2} + \frac{a^2t^{3/2}}{2!} - \frac{a^3t^{5/2}}{3!} + \cdots\right)1 \\ &= \frac{1}{\sqrt{\pi t}}\left(1 - at + \frac{a^2t^2}{2!} - \frac{a^3t^3}{3!} + \cdots\right)1 \\ &= \frac{1}{\sqrt{\pi t}}\epsilon^{-at}1 \end{aligned}\right\} \tag{59}$$

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Automatic Control for Washing Machines

W. J. RUSSELL
MEMBER AIEE

IN 1940 the American people spent $113,580,000 to buy 1,552,666 household washing machines. That is big business! But the only way the washing-machine industry could become a big business, and the only way it can remain a big business, is by supplying machines that fulfill the users' actual needs and desires. In practice, this means that the industry must anticipate by several years what features washing-machine buyers will want.

Design of a household appliance to meet certain requirements is as truly an engineering problem as is the design of a large turbogenerator. This article describes the engineering features of a domestic washing-machine unit intended to require a minimum of attention; a program-control device makes it possible to start the operating cycle at any desired point, so that the complete laundering procedure or any part of it may be performed automatically.

More and more, housewives are demanding completely automatic operation of household electrical appliances, including washing machines. An automatic device relieves the user not only from hard work, but also from the need of giving attention to the operation as it progresses, thus giving him (or usually her!) some much-desired leisure. Furthermore the device eliminates several common causes of poor results: the user's carelessness, error, or lack of skill.

A completely automatic washing, rinsing, and drying machine for domestic use, called the "Laundromat," recently was put on the market. To "do the laundry," the housewife needs only to put the clothes into this machine, set two dials (one marked in terms of the type of fabric being washed, the other in terms of the degree of dirtiness), add soap, bluing, or other substances as desired—and play with the baby awhile. When she returns, the machine will have washed and rinsed the clothes scientifically, spun the water out of them, and stopped.

The Laundromat has been designed to meet the following requirements:

1. It must require no attention from the operator, after the initial loading and setting, and must stop automatically when the operation cycle has been completed. The operator should be able to stop the machine, or to reset it, at any time during the cycle.

2. Loading, starting, and unloading the machine must be convenient and simple.

3. Provision must be made for satisfactorily and safely washing a wide variety of loads, ranging from dainty silk underclothing to greasy overalls—not in the same tubful, of course.

4. Water extraction must be better than can be obtained with other types of machines.

5. During the spinning period, the load automatically must be distributed fairly evenly about the axis of rotation. Vibration due to residual unbalance must be isolated from the frame, the more delicate control units, and the floor.

6. The machine must be economical of time, water, soap, and electricity.

7. Appearance must harmonize with other modern electrical appliances. Dimensions must permit installing in a unified kitchen, matched with standard cabinets and other kitchen equipment.

8. The machine must not require a rigidly anchored, permanent installation.

9. It must be rugged and long-lived, and require no lubrication or other mechanical attention.

10. It must be self-protected from damage due to overloads, overvoltage or undervoltage, interruption of power supply, or improper use. Likewise, it must not subject the user to any hazard.

11. It must not be a source of radio interference.

12. Manufacturing cost must be as low as consistent with the other requirements.

Essentially, the machine consists of a washing unit, driving mechanism, an automatic control system, and an enclosing cabinet. Figures 1 and 2 show the relation of these elements.

CABINET

The cabinet is steel, 36 inches high, 31 inches wide, and 27 inches deep. The upper front panel is inclined at an angle of 30 degrees, to facilitate loading. This also corresponds with the angle of inclination of the tub axis.

WASHING UNIT

The basket is a perforated pear-shaped welded-steel tub finished with vitreous enamel. Integral with it are four vanes, spaced around the periphery, and designed to give to the clothing the desired motion. During the washing and rinsing operations, the basket rotates at 50 rpm; during extraction, at 485 rpm. A steel sleeve is welded to the rear of the basket, and passes through a double water seal to the two-speed drive mechanism. Surrounding the basket is a two-piece enameled steel tub, which supports the drive mechanism, motor, drain pump, and lint trap. At the front of the tub is a sealed

Essential substance of a talk given at the AIEE summer convention in Toronto, Ont., Canada, June 16–20, 1941.

W. J. Russell is manager of engineering, merchandising division, Westinghouse Electric and Manufacturing Company, Mansfield, Ohio.

Figure 1. Cutaway view of Laundromat, with front and top covers removed

A—Temperature selector
B—Heat-resistant glass door, with soap chute
C—Washing basket
D—Vibration control: Three springs support inner washing unit; five snubbers absorb vibration
E—Operating control
F—Lint trap to keep foreign matter from pump
G—One-fourth horsepower a-c motor

glass door for admitting clothing; an auxiliary door admits soap and other substances after the basket has started to rotate. Both tub and basket are self-cleaning.

DRIVING MECHANISM

Power is furnished by a 1/4-horsepower split-phase rubber-mounted motor having special torque characteristics. The motor is connected by a V-belt to the shaft of the two-speed hub, as shown in Figure 3. The high-speed centrifugal drain pump is driven from the same belt when the belt is forced into the pump pulley; except when draining, the pump is at rest. The two-speed hub consists of a planetary-gear drive, a conical clutch, shifting means, and supporting bearings. The steel pinion rotates continuously at 485 revolutions per minute. During the water-extraction period, all parts of the mechanism rotate as a unit. During the washing period the planet gear revolves around the pinion center at 50 revolutions per minute, carrying with it the output sleeve. The complete assembly operates in a bath of oil which provides satisfactory lubrication through the normal expected life of the machine.

The entire washing unit, including driving mechanism, is suspended in the cabinet by three coil springs, which isolate from the frame the vibration forces resulting from a rapidly rotating unbalanced clothes load. Vibration energy is absorbed by five friction dampers. The arrangement of suspension springs and vibration dampers is shown in Figure 1.

AUTOMATIC CONTROL

All operations are electrically controlled by a synchronous-motor-operated program timer, which is set manually at the time the machine is loaded. Inlet water temperature is controlled by a thermostatic mixing valve, also manually set. Combined with this valve are two solenoid valves, actuated jointly by the timer and a water-level switch. The two-speed hub is shifted to washing or spinning speed by a magnetic solenoid, also controlled jointly by the timer and water-level switch. The drain pump is stopped and started by another solenoid which acts through a flexible lever on a roller to force the drive belt against the pump pulley. The drive motor is protected by an automatic-reset thermal relay.

Program Timer. The timer is the "brain" of the whole control system. It actuates each element of the machine in accordance with a predetermined program, shown

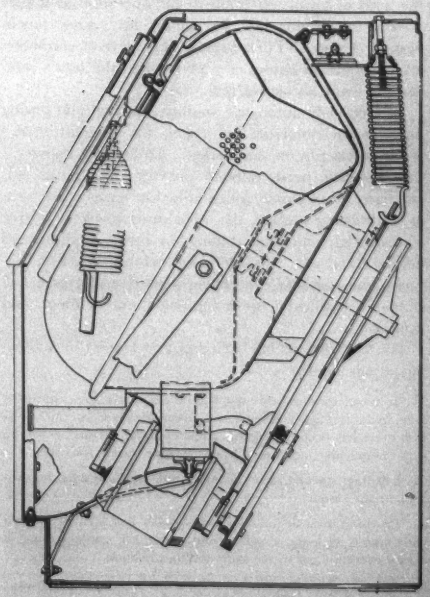

Figure 2. Cross section showing relation of principal design elements

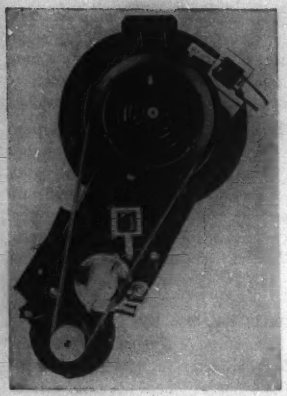

Figure 3. Rear view of drive

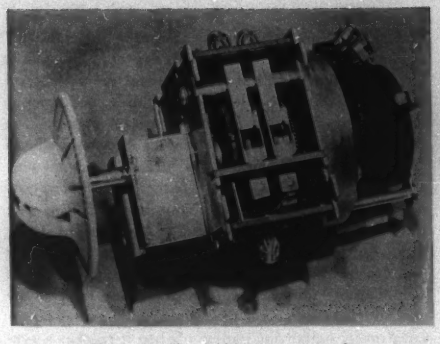

Figure 5. Timer with cover removed

diagrammatically in Figure 4. The normal cycle is as follows:

1. Fill with water of selected temperature, and wash for a period manually adjustable between 7½ and 21 minutes.
2. Drain washing water, spray flush, and spin semidry.
3. Fill with tempered water and rinse for 7½ minutes.
4. Drain rinse water, spin out rinse water, cold spray rinse, spin dry, and stop.

The total time required for the foregoing program is between 21¾ and 35¼ minutes. In addition, provision is made for a prewash, used chiefly for exceptionally dirty clothes.

The timer, shown in Figure 5, contains five switches operated by cams. Each switch consists of two silver contacts, one mounted on a fixed bar, the other on a phosphor-bronze spring with a lug which engages the cam. The camshaft is driven intermittently, through an escapement mechanism, by a sealed and permanently lubricated subsynchronous electric clock motor. Every 45 seconds the camshaft snaps through a five-degree angle, giving a quick make-or-break motion to the contacts. In series with the bus bar for the five contacts is another switch operated by axial motion of the camshaft. This is the main "on and off" switch for the machine. The control dial is attached to the camshaft with a "free wheeling" device. To set the control, the operator turns the dial clockwise; counterclockwise effort on the dial causes it to turn freely on the shaft. This protects cam riders and escapement from damage by preventing backward rotation of the shaft. To start the machine, the operator pushes the dial in; to stop it, he pulls the dial out. With this arrangement, the timer can be set to any selected point of the cycle without actuating the various controls until the operator is ready. The timer contacts and escapement are enclosed in a protective housing.

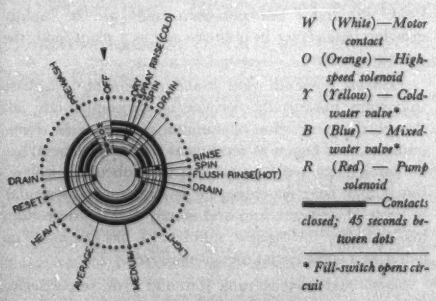

Figure 4. Cycle of time control

Dial is manually set at start of each washing load

Inlet-Water Control. For satisfactory operation, the proper quantity of water, at the proper temperature, must be admitted to the tub at the proper time. To accomplish this requires the interaction of four units: the timer, a thermostatic mixing valve, a double solenoid valve, and a water-level-actuated switch.

As a part of the initial setting, the operator sets a dial to correspond to the type of fabric being washed. This adjusts the mixing valve to the proper temperature for the washing water—140 degrees Fahrenheit for light-colored cotton goods, 110 degrees for goods with non-fast dyes, 80 degrees for woolens, and so on. The valve consists of a spiral bimetal element which actuates a balanced-type needle valve to admit more hot and less cold water, or vice versa, as required.

Mounted directly on the brass casting which houses the thermostatic valve are two solenoid valves. One controls mixed water from the bimetal chamber, the other controls cold water which comes to it through a bypass directly from the cold inlet line. The orifice sizes of the two valves are proportioned to give correct rinsing temperature for each type of fabric. A final spray rinse

in cold water cools the clothes to a comfortable temperature for handling during removal from the machine.

The coils are energized through the timer contacts at the proper time. In the return circuit, the water-level switch, a small toggle switch mounted on a fixed bracket, stops the flow of water when the proper amount is in the tub. The operating lever passes through a slot in the "displacement chamber," a vitreous-enameled steel can about 15 inches high and 3 inches in diameter, connected through a flexible rubber tube to the lint trap housing at the bottom of the tub. The chamber is suspended on a coil spring. Two springs set at an angle pull downward on it, providing the required stability. The chamber fills with water to the same level as the water in the tub. As it fills, it gradually moves downward on its supporting spring. When it reaches a predetermined position, it trips the toggle switch, cutting off the water flow. When the chamber drains, it rises and returns the switch to the closed position in readiness for the next signal from the timer.

Drain Control. The drain pump is actuated by a solenoid-operated lever and roller assembly (see Figure 3). The solenoid, which is energized by the timer at the proper time, consists of a magnet coil in a laminated steel frame, with a laminated steel plunger which slides within the coil between fixed stops. In the "sealed" position, the plunger abuts against the frame at two points to form a magnetic circuit completely in laminated steel.

Speed Control. The shifting lever on the two-speed hub is pulled into the high-speed position by another solenoid similar in construction to the drain solenoid, but larger. This solenoid is energized through still another timer contact, but is interlocked with the water-level switch. This interlock prevents premature spinning, before water has been drained below the level of the spinner basket, thus avoiding overloading the main drive motor.

MOTOR PROTECTION

To safeguard the motor from prolonged high temperatures that would deteriorate the insulation used in its windings, a bimetal disk-type thermostat is used. Motor temperatures vary directly with the square of the motor current, so an auxiliary heater is placed in the thermostat which heats the bimetal as a function of this same current squared. Excessive motor current actuates the protective thermostat before the windings are overheated.

Metals for Tomorrow

Which metals will continue to be used in increasing quantities? Already we are witnessing the phenomenal growth of the light metals. Military planes dictate the expansion of domestic production capacity to 700,000 tons a year for aluminum and 200,000 tons a year for magnesium, representing 5-fold and 100-fold increases compared with the 1937 peak output of the respective metals. When the war is over, efforts will be made to utilize this capacity.

Aluminum ranks third and *magnesium* eighth in order of abundance among the elements. As regards magnesium, we have already begun to utilize a variety of mineral raw materials, drawing supplies from the ocean as well as from magnesite and brucite deposits. The technical difficulties of utilizing alunite, clay, and various other minerals as sources of aluminum have been eliminated, and only the economic factors need to be worked out for us to return to the idea that there is an aluminum mine in virtually every back yard. Hitherto aluminum has ranked far below iron in available ore reserves as well as in cost of commercial extraction.

The steel industry already has confirmed its destiny, as forecast by the abundance of *iron* in the earth's crust, and so far our needs have been satisfied without using extremely low-grade ores. Notwithstanding the tremendous expansion in productive capacity for light metals, we can still produce in the United States 100 times as much steel as aluminum and magnesium combined.

Silicon is second in abundance only to oxygen, but lacks the physical properties of a structural metal, and its larger utilization as an alloying agent and deoxidizer is somewhat discouraged by the high cost of power. *Calcium* and *sodium* are in much the same category. Sodium, of course, is far too active chemically to be used for structural purposes or even to be handled, but hundreds of thousands of tons a year are consumed in chemical syntheses; approximately one pound of sodium is used for every three pounds of tetraethyl lead for antiknock motor fuel. The usefulness of *potassium* as a metal is eclipsed by sodium, which is more efficient and even more abundant, but potassium salts are of rapidly growing importance in industry and as a plant food, the principal outlet.

Titanium, the tenth most abundant element, is likewise important industrially because of its compounds, although the production of titanium pigments, the dominant use, was begun as recently as 1919. The metal has no commercial use because it is too difficult to isolate, but it may bear watching, for it has properties similar to those of wrought iron and is only a little more than half as heavy. *Manganese*, number 13, has just made its debut as a commercial metal, unalloyed.

Barium and *strontium* rank 16th and 19th, respectively. Both have been used industrially, but only in a small way in the metallic state, although uses of their compounds eventually will balance their natural availability.

Abstracted from "Tomorrow's Metals" by Paul M. Tyler, *Mining and Metallurgy*, January 1942.

INSTITUTE ACTIVITIES

North Eastern District Meeting to Include Branch Convention

The forthcoming North Eastern District meeting and Student Branch convention will be held at Schenectady, N. Y., April 29–May 1, 1942, with headquarters in the Van Curler Hotel. Tentative arrangements are being made for four technical sessions, a general session, a student program, entertainment, sports, and trips.

The meeting will open with a general session featuring addresses on the research and engineering aspects of the war-time efforts of the electrical industry. The technical sessions are scheduled tentatively to deal with electronics and communication, electric service, industrial applications of electric power, and power transmission and distribution. Technical conferences are planned on vocational education, statistical methods for control of quality, and mercury boiler operation. In addition, tentative plans for the student program call for a student session, a luncheon, a conference meeting, and a meeting of Student Branch counselors. A special luncheon meeting with addresses and discussions on vocational education also is being arranged.

On the entertainment side, provision is being made for a smoker, banquet, sports program, and some inspection trips, the last being affected by war-time restrictions. Entertainment being planned for women guests by Mrs. A. C. Stevens and Mrs. Everett S. Lee, co-chairmen, includes a luncheon, tea, and a trip.

COMMITTEES

District meeting committee:

E. S. Lee, vice-president, North Eastern District; R. G. Lorraine, secretary, North Eastern District; E. B. Alexander, D. E. Chambers, H. D. Griffith, C. F. Harris, T. M. Linville, J. M. Murray, and G. M. L. Sommerman.

Executive committee making arrangements for the meeting:

T. M. Linville, *chairman;* P. L. Alger, *special luncheon;* G. W. Brucker, *reception;* J. W. Butler, *registration;* F. E. Danford, *banquet;* S. A. Holme, *publicity;* H. H. Race, *meetings and papers;* R. C. Sogge, *sports;* Mrs. A. C. Stevens and Mrs. Everett S. Lee, *women's entertainment;* I. A. Terry, *inspection trips;* and E. A. Walker, *student activities.*

Black-Out Measures Described at Maryland Joint Meeting

New types of black-out measures being developed in the United States were described at a recent joint meeting of the AIEE Maryland Section and the Maryland chapter of the Illuminating Engineering Society at Johns Hopkins University, Baltimore, by Samuel G. Hibben (A'34) director of applied lighting, Westinghouse Lamp Division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J.

Fluorescent and phosphorescent paints may be used for curb and sidewalk markings, for shelter and traffic signs, Mr. Hibben said. Thus pedestrians or vehicles might use special flashlights which generate a small amount of visible blue light and considerable invisible ultraviolet to make the chemical paints luminescent. Reflector buttons can be extremely valuable under black-out or near-black-out conditions, worn by pedestrians as lapel flowers, buttons for coats, brooches, or shoe buckles. Every pedestrian should wear something white—possibly something similar to grandmother's shawl, which could be thrown over the shoulder upon going out, and would make a person more easily seen from both front and rear.

Few of the new types of black-out measures now being worked out contemplate all-out black-outs, Mr. Hibben disclosed. Instead, ways and means of dimming city areas to the level of moonlight, extensive methods of lighting camouflage, plans to befuddle air raiders by scrambling light patterns on the ground are being considered. All vulnerable cities within 600 miles of the nation's coasts, he pointed out, should devise air-raid protection measures, which could be put into operation at a moment's notice, and also would enable a city to return quickly to normal lighting. All strategic objectives should be blacked-out or made indistinguishable from surrounding areas, so that they can not be readily discovered from the air. Major harbors, bridge and highway lights should be darkened so as not to reveal landmarks, he said.

Winter Convention Report to Appear in March Issue

As this issue goes to press the Institute's 1942 winter convention gets under way at New York, N. Y. Early indications are that this convention is continuing the successful record of recent years in spite of the inevitable effects of the war. Registration for the first two days totaled 1,059, as compared with 1,278 for the first two days of the 1941 convention, 1,178 for 1940, and 1,159 for 1939. The March issue will contain the full report of the convention.

Warning! Beware of Photographers!

AGAIN complaints and inquiries to AIEE headquarters indicate that members are being approached by photographers who represent themselves as acting on behalf of the Institute. Consequently, we repeat this warning.

Members are hereby warned that such representations are entirely false. Any members so contacted are invited to send to the national secretary any available information that will help to identify such impostors or the organizations for which they are acting.

ONLY ONE LEGITIMATE CHANNEL

The AIEE editorial department has a working agreement with Bachrach Studios whereby a portrait photograph of any member that is desired for publication or file will be taken by Bachrach Studios without *any* charge to or obligation of the member. Further, the functioning of this arrangement in *each* instance is contingent upon specific arrangements made directly by the editorial department with the member whose portrait is desired. As this is the one and only operating agreement in effect, any other representation alleging AIEE authorization must of necessity be false.

Future AIEE Meetings

North Eastern District Meeting
Schenectady, N. Y., April 29–May 1, 1942

Summer Convention
Chicago, Ill., June 22–26, 1942

Pacific Coast Convention
Vancouver, B. C., September 9–11, 1942

Middle Eastern District Meeting
Pittsburgh, Pa., October 14–16, 1942

PERSONAL . . . .

W. L. Abbott (A'01, F'13) retired chief operating engineer, Commonwealth Edison Company, Chicago, Ill., has been named recipient of the Washington Award for 1942 by the Washington Award Commission. He was born February 14, 1861, Union Grove, Ill., and received from the

University of Illinois the degrees of mechanical engineer and doctor of laws. During 1884–86 he was employed as draftsman for the Ogden Engine Company and the Pullman Palace Car Company and the

W. L. Abbott

following year was a member of the firm of Wunder and Abbott, Electric Light Renters. In 1887 he became president and manager, National Electric Construction Company, Chicago, Ill., and when it was taken over by the Chicago Edison Company in 1895, he became chief engineer of one of the company's powerhouses. He was chief operating engineer of Chicago Edison and its successor, Commonwealth Edison, from 1899 until his retirement in 1936. He is a past president and honorary member of the American Society of Mechanical Engineers and the Western Society of Engineers. He is also a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

H. B. Bryans (M'17, F'18) executive vice-president and director, Philadelphia Electric Company, Philadelphia, Pa., has been elected vice-president of the American Standards Association for the current year. He has been with the United Gas Improvement Company or one of its associated companies since 1907. A representative of the Edison Electric Institute, he has been on the board of directors of the ASA since 1941. **H. S. Osborne** (A'10, F'21) plant engineer, operation and engineering department, American Telephone and Telegraph Company, New York, N. Y., has been elected chairman of the ASA Standards Council. He has been with American Telephone and Telegraph since 1910. He has been Institute representative or alternate on the Standards Council since 1923 (vice-chairman 1940) and on the ASA Electrical Standards committee since 1931. He is currently serving as a director of the Institute, chairman of the finance committee, and a member of the executive, headquarters, planning and co-ordination, Institute policy, and Edison Medal committees and as AIEE representative on the Alfred Noble prize committee. He has served also on the standards committee (chairman 1923–26), communication committee (chairman 1931–34), and technical program committee (chairman 1936–39), and has been a member of the committees on education, award of Institute prizes, publication, legislation affecting the engineering profession, as well as several special committees. He has also been AIEE representative on the American Association for the Advancement of Science, and, since 1923, on the United States National Committee of the International Electrotechnical Commission, serving at present as its vice-president and treasurer. **W. F. Sims** (A'20, F'33) chief electrical engineer, Commonwealth Edison Company, Chicago, Ill., has been appointed a representative on the Standards Council by the ASA Electric Light and Power Group. Since 1916 he has been with Commonwealth Edison. During 1927–37 he served on the power generation committee of the Institute, and 1934–35, on the electric machinery committee. **H. E. Kent** (A'25, M'31) engineer, Edison Electric Institute, New York, N. Y., will serve as an alternate representative. Since 1923 he has been with the Edison Electric Institute. He is currently serving on the communication, domestic and commercial applications, and protective devices committees of the AIEE.

H. H. Barnes, Jr. (A'00, F'13) commercial vice-president, General Electric Company, retired January 1, 1942. Born December 15, 1875, New York, N. Y., he was graduated from Stuttgart Polytechnicum, Wuerttemberg, Germany, 1897. Joining the Charlottenburg Works of Siemens and Halske in that year, he was engaged there in test work and polyphase problems until 1899 when he was transferred to the Mexican Electric Works, Ltd., Mexico City, as general engineer. In 1902 he became staff engineer and later, manager of the engineering department of the Stanley Electric Manufacturing Company, Pittsfield, Mass., now a part of the General Electric Company, and in 1907 he became consulting engineer in the New York office of the latter company. In 1908 he was appointed district engineer and in 1920, assistant manager of the New York district, in 1928 becoming district manager, and in 1930, commercial vice-president. During 1910–13, he served as a manager of the Institute, and 1913–15, as vice-president, in addition to serving on many committees. He has been appointed recently to serve as AIEE executive committee representative on the newly formed Engineers' Defense Board and is AIEE representative on the Hoover Medal Board of Award. He was a trustee of the United Engineering Society (now United Engineering Trustees, Inc.) 1912–17 and 1921–26. He is a past president of the New York Electrical Society, and also a member of the Electrical and Gas Association of New York, and The American Society of Mechanical Engineers.

William McClellan (A'04, F'12) president since 1939 of the Union Electric Company of Missouri, St. Louis, has been elected chairman of the board. He received the degrees of bachelor of science (1900), doctor of philosophy (1903), and electrical engineer (1914) from the University of Pennsylvania and has been connected with that institution as instructor of physics, dean of the Wharton School of Finance and Commerce, and trustee. He was with the Philadelphia Rapid Transit Company 1900–04, engineer with Westinghouse, Church, Kerr and Company, New York, N. Y., 1905–07, and vice-president of the Campion McClellan Company, 1907–09. He was with Paine, McClellan and Campion, 1915–20, and after an interval as vice-president of the Cleveland Electric Illuminating Company, was with McClellan and Junkersfeld until 1929. During 1929–33 he was vice-president, Stone and Webster Engineering Corporation and after holding the position of president of William McClellan and Company, Ltd., 1930–33, he became president of the Potomac Electric Power Company, Washington, D. C., remaining until 1939. He has been a manager, vice-president, and president of the AIEE.

C. O. Bickelhaupt (M'22, F'28) former assistant vice-president of the American Telephone and Telegraph Company, New York, N. Y., has been elected vice-president. Born December 15, 1888, Roscoe, S. Dak., he received from the University of Wisconsin the degrees of bachelor of science in electrical engineering in 1911 and electrical engineer in 1914. From 1911 to 1925 he was employed by the American Telephone and Telegraph Company, after an interval of army service, 1917–19, becoming toll traffic engineer in 1922 and commercial engineer in 1923. He was vice-president, director, and a member of the executive committee of the Cumberland Telephone Company, 1925–26, and held these offices in the Southern Bell Telephone and Telegraph Company, 1925–30, when he became assistant vice-president of the American Telephone and Telegraph Company. He was director of the Bell Telephone Securities Company 1934–36. He has served as vice-president and director of the Institute and has been chairman or member of various committees. He is also a member of the New York Electrical Society.

W. C. White (A'23, M'30) formerly engineer in charge of the vacuum-tube division of the radio and television department, General Electric Company, Schenectady, N. Y., has been appointed director of the new electronics laboratory of the radio and television department. After receiving the degree of electrical engineer from Columbia University in 1912, he entered the General Electric research laboratory as assistant. He was development engineer in the research laboratory 1917–27 and engineer in charge of the vacuum-tube section, research laboratory, 1927–29. In 1929 he became engineer in charge of the vacuum tube engineering department. **O. W. Pike** (A'30, M'36) engineer in the vacuum-tube division has been appointed engineer in charge. After graduating from the University of New Hampshire in 1920 with the degree of bachelor of science, he entered

the General Electric test course, Schenectady, N. Y., was in the research laboratory 1922–30, and since 1930 has been in the vacuum-tube division of the radio and television department.

J. E. Hobson (A'36, M'41) former central-station engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has become director of the electrical-engineering department of the Illinois Institute of Technology, Chicago, Ill. He received the degrees of bachelor of science, 1932, and master of science, 1933, in electrical engineering from Purdue University, and that of doctor of philosophy, 1935, from California Institute of Technology. He was assistant professor of mathematics, Earlham College, Richmond, Ind., 1935–36, and instructor in electrical engineering, Armour Institute of Technology, Chicago, Ill., 1936–37. He joined the Westinghouse company in 1937 and the following year became central-station engineer. He is also a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu and was selected by the latter as "the outstanding young electrical engineer for 1940."

A. G. Jones (A'07) manager of the central station and transportation departments, General Electric Company, San Francisco, Calif., has been appointed manager of the same departments for the Pacific Coast district. He has been with the company since 1905, having entered the test course, Schenectady, N. Y., and having been transferred in 1908 to San Francisco as control specialist. He held various sales positions until he was appointed manager of the central-station department in 1926. **S. W. Scarfe** (M'40) assistant manager of the company's central-station department, Los Angeles, Calif., has been appointed manager. A biographical sketch of Mr. Scarfe appeared in the December 1941 issue, page 602. **B. R. Prentice** (A'35) aeronautics and marine-engineering department, Schenectady, N. Y., has been appointed engineer, aeronautics equipment division.

W. P. Holcombe (A'06, M'13) has retired as vice-president of the Brooklyn (N. Y.) Edison Company. He was born November 20, 1875, Mobile, Ala., and received the degree of bachelor of science in 1896 from Centenary College. After serving in the Spanish-American war, he was employed by the Electric Light Company of Mobile, Ala., in 1901 as assistant superintendent and in 1904 joined the Wesco Supply Company, St. Louis, Mo., as engineer and salesman. Following a period in the sales department of the Frank Adam Electric Company, St. Louis, Mo., he was engaged in electrical contracting work in Detroit, Mich., and in 1920 joined the Brooklyn Edison Company as purchasing agent. In 1926 he was appointed vice-president in charge of purchasing and transportation and in 1938 he was elected vice-president and assistant to the vice-chairman of the board of directors.

C. G. Wallis (A'26) general foreman, Westinghouse Electric Elevator Company, Jersey City, N. J., has been named works manager. He was graduated from Colorado State College with the degree of bachelor of science in electrical engineering and in 1923 became a Westinghouse student engineer at East Pittsburgh, a year later studying at the company's electrical design school. He joined the control engineering department of the East Pittsburgh works in 1924, remaining until 1926 when he became development engineer for the E. I. duPont Company, Charleston, W. Va. In 1928 he joined the Westinghouse Elevator Company, serving as design engineer and chief inspector.

K. E. Dinius (M'40) formerly electrical engineer in the engineering department of the south works, Carnegie-Illinois Steel Corporation, Chicago, has become chief engineer of the south works. In 1924 he received the degree of bachelor of science in electrical engineering from Purdue University. He was employed by the General Electric Company, Fort Wayne, Ind., prior to his joining the Carnegie-Illinois south works in 1924 as a repairman in the electrical department. In 1929 he was appointed testing engineer, becoming superintendent of the electrical department in 1935 and later being transferred to the engineering department.

H. E. Hershey (A'11, M'21) in charge of technical publications for the Automatic Electric Company, Chicago, Ill., was admitted to practice to law in Illinois on November 10, 1941, having graduated in June 1941 from the John Marshall Law School with the degree of doctor of jurisprudence. He received the degrees of bachelor of science in electrical engineering in 1910 and electrical engineer in 1922 from Kansas State College. Since 1910 he has worked continuously for the Automatic Electric Company in various engineering capacities, except for a period of military service.

John West (A'10, M'28) regional executive of the New England Power System, Boston, Mass., has been elected president of the Worcester County Electric Company, Worcester, Mass. Born February 17, 1886, he was educated at Mount Saint Mary College and Harvard University. He was employed by the Edison Electric Light and Power Company, Montgomery, Ala., and after holding several engineering positions in the utility field he joined the New England Power group about ten years ago as operating manager of a group of companies northeast of Boston.

V. K. Zworykin (M'22) associate director, research laboratories, RCA Manufacturing Company, Camden, N. J., was recently awarded the Rumford Medal of the American Academy of Arts and Sciences for "outstanding contributions to the subject of light." He worked on telegraphy for the Russian government, before joining the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., as research engineer in 1920. Since 1929 he has held his present position. He has received several prizes and awards and is the author of technical books and articles.

W. H. Harrison (A'20, F'31) has been named as head of the production division of the War Production Board, Washington, D. C., set up in January to replace the former Office of Production Management. Mr. Harrison, on leave as a vice-president from American Telephone and Telegraph Company, New York, N. Y., headed the OPM production division. He has been in Washington since June 1940 (*EE, Oct. '41, p. 506*).

W. D. Coolidge (A'10, M'34) director, research laboratory, General Electric Company, Schenectady, N. Y., has recently received the Duddell Medal of the Physical Society, London, England, for producing ductile tungsten from the powdered metal and developing the heated-filament-cathode X-ray tube. He has been with the research laboratory of General Electric since 1905 and has been the recipient of numerous medals and honors.

W. B. Kouwenhoven (A'06, F'34) professor of electrical engineering and dean, school of engineering, Johns Hopkins University, Baltimore, Md., has been honored by the Resistance Welders Manufacturers' Association for a paper contributing to progress in resistance welding.

R. E. Thornton (M'32) engineer, Arkansas division, Oklahoma Gas and Electric Company, Fort Smith, Ark., has been appointed distribution engineer of the general office engineering department, Oklahoma City. He has been with the Oklahoma Gas and Electric Company since 1923.

W. E. Mitchell (A'06, F'22) vice-president and general manager, Georgia Power Company, Atlanta, has been appointed chairman of the utilities division of the Greater Atlanta Defense Council.

William Kelly (F'25) president and director of the Buffalo, Niagara, and Eastern Power Corporation, Buffalo, N. Y., has been awarded honorary membership in the American Society of Civil Engineers.

D. C. Stewart (A'25, M'35) safety department manager, Buffalo, Niagara and Eastern Power Corporation, has been appointed safety supervisor for the Niagara Hudson system.

M. S. Beisber (A'37) former branch manager, Line Material Company, Memphis, Tenn., has been appointed West Coast transformer specialist with headquarters at Oakland, Calif.

A. R. Willson (M'35) formerly of the Washington State Department of Public Service, Seattle, has joined the engineering staff of the Boeing Aircraft Company, Seattle, Wash.

B. R. Frits (M'33) former consulting electrical engineer, G. M. Simonson Company, San Francisco, Calif., has been made electrical engineer, Camp Roberts, Calif.

T. W. Conrad (A'38) of the sales department, Graybar Electric Company, Tulsa, Okla., has been appointed acting manager of the company's Omaha, Nebr., office.

OBITUARY

Philip Torchio (A'95, M'04, F'12) retired vice-president of Consolidated Edison Company of New York, Inc., New York, N. Y., died January 14, 1942. He was born August 2, 1868, at Vercana, Como, Italy, and received the degree of bachelor of arts from the University of Pavia, 1890, and the degrees of mechanical engineer and electrical engineer from the Royal Polytechnic of Milan, 1893, having taken special work in electrical engineering at the Institute Carlo Erba. In 1893 he came to New York and was employed as draftsman and chief draftsman by the Sprague Electric Elevator Company, 1893–95. He became draftsman for the Edison Electric Illuminating Company of New York in 1895, continuing with that company and its successors, the New York Edison Company and Consolidated Edison Company of New York, until his retirement in 1938. He was engineer of economics, 1895–1901; engineer of distribution, 1901–05; chief electrical engineer, 1905–24; vice-president, 1924–38; and also served as consulting engineer for several associated electric companies, 1905–28. He was the author of many technical papers and held various patents for electrical apparatus. He was member or chairman of many AIEE committees and was awarded the Edison Medal for 1939. He was also a member of the Franklin Institute, Illuminating Engineering Society, Associazione Ellettrotechnica Italiana, New York Electrical Society (past president), and an Institute representative on the American Engineering Council.

William Spencer Murray (A'03, M'05, F'12) chairman of the board of directors, Murray and Flood, Inc., New York, N. Y., died January 9, 1942. Born in 1874, Annapolis, Md., he received the degree of electrical engineer from Lehigh University in 1895 and entered the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., as an apprentice. After holding various positions, he was transferred to Boston as district engineer in charge of the New England territory in 1898. He practiced as a consulting engineer from 1902 to 1905 when he joined the New York, New Haven and Hartford Railroad, New Haven, Conn., as electrical engineer in charge of electrifying the road from New York to New Haven. While continuing to serve as consulting engineer for the latter, he joined E. H. McHenry in founding the firm of McHenry and Murray in 1913, continuing until 1917. During World War I, recognizing the economy in a unified system of power production, he proposed a superpower survey and served as chairman of the committee and chief engineer of the project. In 1921 he joined Henry Flood, Jr., in the formation of the engineering firm, Murray and Flood, Inc., and became chairman of the board. About six years later, perceiving the possibility of new power development, he started work on the Saluda River hydroelectric project, South Carolina, and completed what was then said to be the largest dam in the world. He was a manager of the Institute, 1908–12, and vice-president, 1912–14, as well as a member of many committees. He was also the author of many technical papers.

Otto Rothenstein (A'28) retired engineer, died October 20, 1941. He was born August 9, 1872, Teplitz, Czechoslovakia, and educated in Vienna. He was employed by General Electric Company, Schenectady, N. Y., in 1895, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1896, and Smith Vassar Telephone Company, New York, N. Y., in 1897. He did experimental work for the Thermo Electric Company, New York, N. Y., 1897–99 and after working with the Lewis Foundry and Machine Company, Pittsburgh, Pa., and the Bradley Manufacturing Company, Allegheny, Pa., he joined W. Scheidel and Company in 1904, remaining until 1907. From 1907 until 1925 he was engaged in X-ray work and the designing of scientific instruments and in 1925 was with the bureau of design of the Board of Local Improvements, City of Chicago, Ill. After working in various engineering capacities for Adams and Westlake, and the Mechanical Manufacturing Company, both of Chicago, he entered the engineering department of Barrett Cravens Company, Chicago, in 1927, and in 1930 joined the Louden Machinery Company, Fairfield, Iowa. He was electrical engineer for the Metropolitan Manufacturing and Electric Company, Chicago, Ill., 1930–37.

Frank Cordley Clark (A'12) general manager, Nitrogen Division, The Solvay Process Company, Hopewell, Va., died October 28, 1941. Born July 3, 1881, Ogden, Utah, he was graduated from Armour Institute of Technology with the degree of bachelor of science in electrical engineering. He was employed as draftsman by the Commonwealth Edison Company, Chicago, Ill., 1905–09, and as assistant engineer by the Isthmian Canal Commission, 1909–16. He was with the Newcastle Construction Company, 1916–18 and became plant superintendent of the American Can Company. After an interval of consulting practice, 1921–22, he became engineer for Lockwood, Greene, and Company. During 1924–26 he was factory manager, Cutting and Washington Radio Corporation and in 1926 he became general manager, Atmospheric Nitrogen Corporation, now Nitrogen Division, Solvay Process Company. He was also a member of the American Society of Mechanical Engineers.

Howard Mason Van Gelder (A'05, M'13), retired electrical engineer, died November 22, 1941. Born December 15, 1876, Catskill, N. Y., he graduated from Brown University in 1897 with the degree of mechanical engineer. He was employed by the General Electric Company, Schenectady, N. Y., from 1897 to 1900 when he joined the Manhattan Elevated Railway Company, New York, N. Y. In 1903 he joined Westinghouse, Church, Kerr, and Company, New York, now a part of Westinghouse Electric and Manufacturing Company where he remained for 20 years. He was later associated with Gibbs and Hill, engineers, New York, N. Y.; Canadian Pacific Railway, Vancouver, B. C.; department of city transit, Philadelphia, Pa. He was successively chief electrification engineer for the Federal Power Commission, Washington, D. C.; electrical engineer for the New York, Westchester and Boston Railway, N. Y., as well as chief electrical engineer with the Pennsylvania Turnpike Commission.

Paul Augustinus (M'27) president and treasurer of the Marquette Electric Switchboard Company, Chicago, Ill., died November 18, 1941. Born March 13, 1873, in Denmark, he received the degree of bachelor of science in electrical engineering in 1906 from the University of Illinois. In 1906 he entered the Western Electric Company, Hawthorne, Ill., where he was engaged in switchboard and arc-lamp engineering until 1910 when he joined the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., as switchboard engineer. From 1912 to 1917 he was employed by Henry Newgard and Company, Chicago, Ill., in charge of the switchboard department, joining the Marquette Electric Engineering Company (now Marquette Electric Switchboard Company) in 1917 as manager of the switchboard department and vice-president until 1922, when he became general manager as well as president and treasurer. He was also a member of Tau Beta Pi.

James H. Cunningham (A'06) manager of the central-station department, General Electric Company, Los Angeles, Calif., died October 29, 1941. Born in 1883 at Schenectady, N. Y., he was graduated in 1905 from the electrical engineering course of Union College, from which he received a master's degree in electrical engineering in 1910. He spent a year in the testing department of the General Electric Company, Schenectady, before being appointed instructor in electrical engineering at Union College. He went to Los Angeles in 1913 as a member of the small-motor department of the General Electric Company and was engaged in sales work in that district from 1917 to 1926, when he became manager of the central-station department.

Edward D. Swinburne (A'08) former manager of the power plant of the National Biscuit Company, New York, N. Y., died November 12, 1941. Born December 9, 1865, Milwaukee, Wis., in 1888 he received the degree of bachelor of mechanical engineering from the University of Wisconsin. After holding various positions in the electrical construction field, in 1900 he became electrician for the Whitman and Barnes Manufacturing Company. In 1904 he became electrical engineer for the National Biscuit Company becoming manager of its New York power plant about five years later, and continuing in that position until his retirement in 1929. He was also a member of the New York Electrical Society.

Ernest Frank Smith (A'07, F'21) retired superintendent of substations, Commonwealth Edison Company, Chicago, Ill., died November 13, 1941. He was born October 9, 1876, Elburn, Ill. and had been employed by Commonwealth Edison since 1894. He first did testing and operating work, and later held positions as foreman, assistant to the chief operating engineer, and superintendent of substations. He was also a member of the National Electric Light Association, Western Society of Engineers, and the Institute of Radio Engineers.

Alonzo B. See (A'93) retired president, A. B. See Elevator Company, New York, N. Y., died December 16, 1941. He was born in 1847 and founded the A. B. See Elevator Company in 1883, expanding the business until it was one of the leaders in its field. Although he retired in 1930 after having been president of the company since its beginning, the family retained controlling interest and in 1937 it was decided to sell the property to the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., of which it is now a subsidiary.

Howard Van Rugg (A'07, M'13) special representative, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., died September 21, 1941. He was born April 28, 1874, Brodhead, Wis. Since 1894 he had been employed by Westinghouse Electric and Manufacturing Company, serving as an apprentice in the works until 1898 when he entered the testing department. He was erection engineer in the New York City office 1902–05 and district engineer of the Philadelphia district 1905–39. In 1939 he became special representative.

Alfred Euclid Poirier (A'01) retired real-estate dealer, died December 17, 1941. Born September 13, 1858, he was educated privately. He practiced watchmaking 1876–87 and was with the United States Treasury Department 1887–89. In 1889 he was employed by the Western Electric Company and in 1896 he joined the New York and New Jersey Telephone Company, remaining until 1908. In 1909 he was president and treasurer of A. Barnes, Importers, New York, N. Y., and prior to his retirement, he was engaged in property management.

Julian Roe (A'06) western sales manager, Crocker-Wheeler Electric Manufacturing Company, Chicago, Ill., died November 24, 1941. He was born in 1868, Zurich, Switzerland, and had been with the Crocker-Wheeler Electric Manufacturing Company since 1893, first serving as erector of machinery, and as salesman. In 1899 he was appointed Chicago district manager and since 1927 had been western sales manager. He was also a member of the National Electrical Manufacturers Association, and the Association of Iron and Steel Engineers.

MEMBERSHIP

Recommended for Transfer

The board of examiners, at its meeting on January 22, 1942, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Adams, L. F., assistant to vice-president and manager of standards department, General Electric Company, Schenectady, N. Y.
Armor, J. C., electrical engineer, Allis-Chalmers Manufacturing Company, Pittsburgh, Pa.
Crowell, G. F., chief engineer, Wisconsin Telephone Company, Milwaukee, Wis.
Dambly, H. A., assistant engineer in charge, special investigation and testing division, Philadelphia Electric Company, Philadelphia, Pa.
Downing, F. M., vice-president and general manager, Pacific Gas and Electric Company, San Francisco, Calif.
Dyche, H. E., professor and head, electrical engineering department, University of Pittsburgh, Pittsburgh, Pa.
Morton, W. B., senior field engineer, Philadelphia Electric Company, Philadelphia, Pa.
Willis, C. H., professor of electrical engineering, Princeton University, Princeton, N. J.

8 to grade of Fellow

To Grade of Member

Appleton, W. E., Major, Signal Corps, Governors Island, N. Y.
Bissett, E., electrical transmission engineer, San Antonio Public Service Company, San Antonio, Tex.
Crossman, G. C., assistant engineer, Consolidated Edison Company of New York, Inc., New York, N. Y.
Forbes, A. D., section engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Grondahl, L. O., director research and engineering, Union Switch and Signal Company, Swissdale, Pa.
Henningson, H. H., consulting engineer, Henningson Engineering Company, Omaha, Nebr.
Lawson, F. C., chief operator, Abitibi District of Hydro Electric Power Commission, Fraserdale, Ont.
Moses, Rufus, division manager, Pennsylvania Power Company, Sharon, Pa.
Perry, A. M., electrical inspector of factories, Ministry of Labor and National Service, Victoria, London, England.
Sill, H. D., electrical superintendent, Indiana and Michigan Electric Company, South Bend, Ind.
Snyder, F. L., electrical engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Stelzner, W. A., engineer, Commonwealth & Southern Corporation, Jackson, Mich.
Talama, C., field engineer, General Electric Company, Omaha, Nebr.
Tames, J. A., sales engineer, Canadian Westinghouse Company Ltd., Vancouver, B. C.

14 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before January 31, 1942, or March 31, 1942 if the applicant resides outside of the United States or Canada.

United States and Canada

1. North Eastern

Adams, G. J., General Electric Company, Schenectady, N. Y.
Bersbach, A. J., General Electric Company, Schenectady, N. Y.
Black, R. A., General Electric Company, Schenectady, N Y.
Brighty, W. B., General Electric Company, Schenectady, N. Y.
Coughlin, J. P., General Electric Company, Schenectady, N. Y.
Gitzendanner, L. G., General Electric Company, Schenectady, N. Y.
Gollin, N. W., Taylor Instrument Companies, Rochester, N. Y.
Kelley, G. W., General Electric Company, Lynn, Mass.
King, E. F., General Electric Company, Schenectady, N. Y.
Kraus, H. L., Dunham Laboratory, Yale University, New Haven, Conn.
Lippitt, K. H., International Business Machines Corporation, Endicott, N. Y.
Mancib, A. S., Jr. (Member), Hygrade-Sylvania Corporation, Salem, Mass.
Marshall, J. W., General Electric Company, Schenectady, N. Y.
McCarron, J. F., Jr., Stone and Webster Engineering Corporation, Boston, Mass.
Miller, W. S., General Electric Company, Schenectady, N. Y.
Millhouse, S. D., Revere Copper and Brass, Inc., New Bedford, Mass.
Moore, R. E., General Electric Company, Schenectady, N. Y.
Olson, F. A., General Electric Company, Lynn, Mass.
Paquin, E. W., American Steel and Wire Company, Worcester, Mass.
Pealee, L. R., Coast Artillery, United States Army, Sagamore, Mass.
Phillips, J. D., General Electric Company, Schenectady, N. Y.
Preston, F. S., Massachusetts Institute of Technology, Cambridge, Mass.
Rollins, F. F., Niagara Falls Power Company, Niagara Falls, N. Y.
Smith, O. J. M., Tufts College, Medford, Mass.
Sugnet, R. F., 155 Sterling Avenue, Buffalo, N. Y.
Verrechia, D. A., 542 Charles Street, Providence, R. I.
Wilder, W. W., Jr., Submarine Signal Company, Boston, Mass.

2. Middle Eastern

Aufmuth, R. H., Lincoln Electric Company, Cleveland, O.
Bartholomee, T. M., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Beggs, G. E., Jr., Leeds and Northrup Company, Philadelphia, Pa.
Bott, H. F., Carnegie Illinois Steel Corporation, Youngstown, Ohio.
Bradfield, H. J., Navy Department, Bureau of Ships, Washington, D. C.
Brauer, D. W., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Burger, E. J. (Member), Ohio Public Service Company, Lorain, O.
Carroll, F. W. (Member), Rural Electrification Administration, Washington, D. C.
Carter, R. F., United States Army Signal Corps, Fort George G. Meade, Md.
Case, R. D., Jr., Westinghouse Electric and Manufacturing Company, Pittsburgh, Penna.
Christian, R. L., The Lincoln Electric Company, Cleveland, Ohio.
Cohen, H. C., Jr., Rural Electrification Administration, Washington, D. C.
Dakers, D., Clark Controller Company, Cleveland, O.
Davidson, W. M., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna.
Dike, S. H., Carnegie Institution of Washington, Washington, D. C.
Dunnigan, A. F. (Member), Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Eckert, R. P., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Exner, D. W. (Associate re-election), Westinghouse Electric and Manufacturing Company, Lima, Ohio.
Forbes, R. S., Jr., General Electric Company, Philadelphia, Pa.
Foxall, E. C., Cleveland Electric Illuminating Company, Cleveland, O.
Geisert, M. E., The Toledo Edison Company, Toledo, Ohio.
Goldstein, D., Public Service Commission, Baltimore, Md.

Grim, L. A., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Hatchard, D. G., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.
Hunt, R. W., Carnegie Illinois Steel Corporation, Youngstown, Ohio.
Kapiloff, E., Catholic University of America, Washington, D. C.
Keistman, A. R., Jack and Heintz, Inc., Cleveland, Ohio.
Laurent, G. J., United States Naval Academy, Annapolis, Md.
Lewis, J. A., Ideal Electric and Manufacturing Company, Mansfield, Ohio.
Lewis, W. A., Rural Electrification Administration, Washington, D. C.
Loustaunau, J. J. (Associate re-election), Western Electric Company, Baltimore, Md.
Marsden, D. J., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Maslin, A. J. (Associate re-election), Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Michener, A. E., Clark Controller Company, Cleveland, O.
Mickelson, T. H., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Mollenauer, K. F., American Cyanamid and Chemical Corporation, Bridgeville, Pa.
Mulberry, F. L., Jr., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Murray, L., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Nagle, R. E., New York Shipbuilding Corporation, Camden, N. J.
Parks, J. B., Jr., Navy Department, Bureau of Ordnance, Washington, D. C.
Perlsweig, A. M., Bureau of Ships, Navy Department, Washington, D. C.
Polster, N. E., Leeds and Northrup Company, Philadelphia, Pa.
Reizenstein, H. S., Jr., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Rodee, H. H., Aluminum Company of America, Pittsburgh, Pa.
Rose, L. H., University of Dayton, Dayton, Ohio.
Seiwert, R. C., Ohio Brass Company, Barberton, Ohio.
Smith, N. L., Jr., Bureau of Ordnance, Navy Department, Philadelphia, Pa.
Stankevich, J. E., Jr., Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Penna.
Stetz, W. V., 218 Madison Street, Riverside, N. J.
Stowe, J. B. R., Sun Shipbuilding and Drydock Company, Chester, Penna.
Tangel, J. E., Bethlehem Steel Company, Bethlehem Pa.
Wagar, A. E., Container Corporation of America, Circleville, O.
Wheeler, W. C., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Woodard, G. H. (Member), Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Penna.
Wise, J. W., Naval Ordnance Laboratories, Washington, D. C.
Young, C. E. (Associate re-election), Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
Zimmerman, R. W., Clark Controller Company, Cleveland, O.

3. New York City

Andrews, G. B., Sperry Gyroscope Company, Inc., Garden City, N. Y.
Ballantine, S. (Member), Ballantine Laboratories, Inc., Boonton, N. J.
Bancroft, E. P. (Member), International Standard Electric Corporation, New York, N. Y.
Dahlberg, S., Fidelity and Casualty Company, New York, N. Y.
Field, K. S., Ebasco Services, Inc., New York, N. Y.
Fredrickson, R. H., Public Service Electric and Gas Company, Newark, N. J.
Geib, J. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Grossi, A., Wessel Duval and Company, New York, N. Y.
Hansel, P. G., Signal Corps Laboratories, Fort Monmouth, N. J.
Henneberger, T. C. (Member), Bell Telephone Laboratories, Incorporated, Murray Hill, N. J.
Johansson, A. S., Westinghouse Electric International Company, New York, N. Y.
Keat, S. H. (Member), Public Service Electric and Gas Company, Newark, N. J.
Knoop, W. A., Jr., Allen B. Dumont Laboratories, Inc., Passaic, N. J.
Panaini, F. J., Department of Public Works, New York, N. Y.
Phinney, E. D. (Member), International Telephone and Telegraph Corporation and International Standard Electric Corporation, New York, N. Y.
Roth, W. S., United States Navy, Nyack, N. Y.
Schramm, M. C., Federal Shipbuilding and Dry Dock Company, Kearny, N. J.
Stieglitz, S. J. (Associate re-election), Consolidated Edison Company, New York, N. Y.
Tatum, F. W., American District Telegraph Company, New York, N. Y.
Yunker, P. J. (Associate re-election), Public Service Electric and Gas Company, Hackensack, N. J.

4. Southern

Barton, L. M., Route # 1, Taylors, S. C.
Campbell, T. C., Jr., Army Air Corps, Craig Field, Selma, Ala.
Carter, R. S., Jr., Tennessee Valley Authority, Lenoir City, Tenn.
Combs, A., Kentucky and West Virginia Power Company, Hazard, Ky.
Cook, W. D., United States Engineers, Brookley Field, Mobile, Ala.
Cooper, A. J., Robert and Company, Inc., Jacksonville, Fla.
Frazier, H. A., Virginia Electric and Power Company, Richmond, Va.
Garlington, W. L., Florida Power Corporation, St. Petersburg, Fla.
Graham, G. E., Naval Air Station, United States Marine Corps, Jacksonville, Fla.
Graves, W. H., East Tennessee Light and Power Company, Johnson City, Tenn.
Hall, P. K., Jr., L. O. Brayton and Company, De Ridder, La.
Harris, H. G., Tennessee Valley Authority, Memphis, Tenn.
Helm, W. D., Century Electric Company, Atlanta, Ga.
Jett, C. O., United States Signal Corps, War Department, Lexington, Ky.
Lewis, W. C., Harrison-Wright Company, Charlotte, N. C.
Morrow, O. J., Havens and Emerson, Fort Knox, Ky.
Pepper, H. A., Tennessee Valley Authority, Wilson Dam, Ala.
Sexton, R. M., Corps of Engineers, United States Army, Langley Field, Va.
Starks, J. P., II, American Air Filter Company, Inc., Louisville, Ky.
Stewart, H. C., Jr., 213 South Cameron Street, Winchester, Va.
Thompson, W. B., Florence Electricity Department, Florence, Ala.
Tunison, T. E. (Member), United States Naval Air Station, Pensacola, Fla.
Wiedenpahn, W. H., Goodyear Tire and Rubber Company, Gadsden, Ala.
Wilson, H. S., Calhoun Falls, S. C.

5. Great Lakes

Aloc, A. H., 508 Thompson Street, Ann Arbor, Mich.
Altman, A. D., Todd and Brown, Inc., Kingsbury, Ind.
Ankeney, H. E., Cutler-Hammer, Inc., Chicago, Ill.
Bank, T. G., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Brickner, H. E., Central Illinois Light Company, Peoria, Ill.
Brumbaugh, J. W., Square D Company, Milwaukee, Wisc.
Burdick, A. H., Jr., Dean W. Davis and Company, Inc., Kentland, Ind.
Cooley, C. W., Michigan Bell Telephone Company, Lansing, Mich.
Copps, L. A., American Hoist and Derrick Company, St. Paul, Minn.
Dunifon, J. W., Utah Products Company, Chicago, Ill.
Fisher, T., Cutler-Hammer, Inc., South Bend, Ind.
Frischauf, S. H., Electric Auto-Lite, Port Huron, Mich.
Hanford, R. I. (Member), ILG Electric Ventilating Company, Chicago, Ill.
Hoehn, A. J., Jr., Commonwealth Edison Company, Chicago, Ill.
Jacobs, L. F. (Member), St. Norbert College, West DePere, Wisc.
Nelson, E. M., I. A. Bennett Company, Chicago, Ill.
Ploetz, G. P., Square D Company, Milwaukee, Wisconsin.
Sellenberg, J. R., Bendix Products Division, South Bend, Ind.
Shepherd, P. D., Consumers Power Company, Jackson, Mich.
Weaver, H. E., Public Service Company of Northern Illinois, Chicago, Ill.
Weldy, L. L., I-T-E Circuit Breaker Company, Chicago, Ill.
Wickman, J. H. (Associate re-election), Consulting Engineer, Jonesville, Mich.

6. North Central

Orr, E. G., Corps of Engineers, United States Army, Fort F. E. Warren, Wyo.

7. South West

Becker, F. A. J., St. Mary's University, San Antonio, Texas.
Beckwith, W. K., Union Electric Company of Missouri, St. Louis, Mo.
Goddard, E. G., Rice Institute, Houston, Texas.
Musler, A. A., Union Electric Company of Missouri, St. Louis, Mo.
Parker, M. R., Union Electric Company of Missouri, St. Louis, Mo.
Scheiner, S. R., S. C. Sachs Company, St. Louis, Mo.
Schnick, E. R., Union Electric Company of Missouri, St. Louis, Mo.
Summers, F. R., Westinghouse Electric and Manufacturing Company, St. Louis, Mo.
Varney, H. S., Phillips Petroleum Company, Bartlesville, Okla.
Yates, C. C. (Member re-election), Southwestern Bell Telephone Company, Kansas City, Mo.

8. Pacific

Best, L. M., General Electric Company, Los Angeles, Calif.
Fuqua, H. E. (Associate re-election), General Electric Company, Los Angeles, Calif.
Jones, L. W. (Member), University of Redlands, Redlands, Calif.
King, H. R., Bureau of Power and Light, Los Angeles, Calif.
McNamer, A. V., Department of Water and Power, Los Angeles, Calif.
Mirk, D. A., Bethlehem Steel Corporation, San Francisco, Calif.
Peterson, R. A., Signal Office, United States Army, Camp Cooke, Lompoc, Calif.
Smith, C. R. (Member), Central Arizona Light and Power Company, Phoenix, Ariz.
Stacy, R. E., United States Army, Santa Rosa, Calif.
Villard, O. G., Jr., Stanford University, Stanford University, Calif.
Walther, A., C. C. Moore and Company, Mare Island, Calif.
Williams, C., Douglas Aircraft Company, Santa Monica, Calif.

9. North West

Beardslee, C. E., Montana Power Company, Butte, Mont.
Boyles, R. M., Tacoma Light Department, Tacoma, Wash.
Buck, A. M. (Associate re-election), Weyerhaeuser Timber Company, Everett, Wash.
DesCamp, E. J. (Member re-election), Graybar Electric Company, Seattle, Wash.
Doucette, C. R., Puget Sound Power and Light Company, Tacoma, Wash.
Falls, C. D., Bureau of Reclamation, Yakima, Wash.
Manke, G. H., Tacoma Light Department, Tacoma, Wash.
Manning, H. M., Tacoma Department of Public Utilities, Tacoma, Wash.
Polley, L. P. (Associate re-election), City of Tacoma, Tacoma, Wash.
Rehkopf, C. L., 2457 First Avenue, North, Seattle, Wash.
Rotta, A. E., Bonneville Power Administration, Vancouver, Washington.
Schaller, P., United States War Department, Fort Lewis, Wash.

10 Canada

Cochrane, J. W., Canadian General Electric Company, Limited, West Toronto, Ont.
Crane, G. J., Canadian General Electric Company, Limited, Toronto, Ont.
Griffiths, G., 1070 Haro Street, Vancouver, B. C.
Hind, R. C., Canadian General Electric Company, Toronto, Ont.
Mason, V. V., 1355 Kingston Road, Toronto, Ont.

Total, United States and Canada, 190

Elsewhere

Bhandari, R. C. (Member), Benares Hindu University, Benares, India.
Gulevich, J. H., U. S. Naval Air Station, San Juan, Puerto Rico.

Total, elsewhere, 2

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Accioly, Pompeu Barbosa, Caixa Postal 571, Rio de Janeiro, Brazil, S. A.
Anderson, Axel W., Jr., 647 W. Sheridan Road, Chicago, Ill.
Andreasen, Ingwald A., 230—75th St., Brooklyn, N. Y.
Butler, N. O., Route 1, Moore, Okla.
Butler, Oliver D., 1355 E. 47th Place, Chicago, Ill.
Daily, Charles S., Jr., 1723 Eye St., N. W., Washington, D. C.
Dennis, Roman, Jr., 360 Amherst St., Buffalo, N. Y.
DeWestfelt, Gerard P., 1211 York Ave., New York, N. Y.
Farmer, Lee Linsey, Balboa Heights, C. Z.
Goudy, Paul R., 8615 Euclid Ave., Cleveland, Ohio.
Innis, Harry H., 5325 Forbes St., Pittsburgh, Pa.
Jackson, Boris Anton, 54 Wendell Ave., Pittsfield, Mass.
Lofstrand, A. L., Box 5043, Quarry Heights, C. Z.
Monks, W. E., 837—22nd St., N. W., Washington, D. C.
Nungester, Jay L., 930 S. Lincoln, Spokane, Wash.
Roberts, C. F., Jr., Houston Lighting & Power Co., Engg. Dept., Box 1700, Houston, Texas.
Smith, Henry A., 4232 Baring Ave., East Chicago, Ind.
Thompson, Haddon, Steeden, Minn.
Whitescarver, Robert S., 400 Center St., Wilkinsburg, Pa.

19 Addresses Wanted

OF CURRENT INTEREST

Field Offices Facilitate War Production

Three plans for further mobilization of the nation's war-production facilities currently are being pushed by the Office of Production Management*: (1) industry-wide conversion of many durable goods industries from civilian to war production; (2) promotion of "war-production associations"; and (3) further subcontracting to individual plants through local offices of the contract distribution division of OPM. Smaller manufacturers that have been deprived of raw materials for their normal production can thus enter into war production through any of these channels. It has been estimated that to turn out the tremendous volume war orders now in prospect will require that all suitable "moderate size" plants in the United States be utilized.

The domestic washer and ironer industry is the first to achieve industry-wide conversion to war production, and has received contracts to manufacture machine-gun mounts. Because of the necessity for large-scale results in the shortest possible time, OPM is now concentrating on industry-wide conversion. In this conversion effort, all branches of OPM are working closely

Field Offices of the Division of Contract Distribution of the Office of Production Management*

Office	Manager	Address
Alabama		
Birmingham*	L. E. Geohegan	Phoenix Bldg.
Arizona		
Phoenix*	F. F. Schalmo	Security Bldg.
Arkansas		
Little Rock*	A. M. Lund	Rector Bldg.
California		
San Francisco	Col. F. M. Smith	Furniture Mart
Fresno	E. H. Cameron	Mattei Bldg.
Los Angeles	Howard Hutchins	1031 S. Broadway
Oakland	W. P. Collins	Financial Center Bldg.
San Diego	P. C. Farmer	Union Bldg.
Colorado		
Denver*	C. C. Hartzell	U. S. Natl. Bank Bldg.
Connecticut		
Hartford*	Carl Gray	Phoenix Bank Bldg.
Bridgeport	R. L. French	Professional Bldg.
Delaware		
Wilmington*	B. L. Giest	Penn Bldg.
Florida		
Jacksonville*	C. C. McCubbin	Hildebrandt Bldg.
Miami	F. D. Banning	Congress Bldg.
Tampa	A. B. Hale	Wallace S. Bldg.
Georgia		
Atlanta*	W. C. Cram, Jr.	Hurt Bldg.
Idaho		
Boise*	H. W. Bogie	Capital Sec. Bldg.
Illinois		
Chicago*	T. S. McEwan	20 N. Wacker Dr.
Springfield	Edward Gerrity	Leland Office Bldg.
Indiana		
Indianapolis*	Frank Hoke	Circle Tower Bldg.
Evansville	J. T. Mooney	Koenig Bldg.
Iowa		
Des Moines*	George Beese	Crocker Bldg.
Kansas		
Wichita*	Harold Hartzell	Union Nat'l. Bank Bldg.
Kentucky		
Louisville*	P. M. Terry	Todd Bldg.
Louisiana		
New Orleans*	R. E. Judd	Canal Bldg.
Shreveport	R. H. Cone	Giddens Lane Bldg.
Maine		
Portland*	Herbert Payson, Jr.	443 Congress St.
Bangor	C. E. Walker	363 Union St.
Maryland		
Baltimore*	G. W. Creighton	Fed. Res. Bank Bldg.
Massachusetts		
Boston*	E. V. Hickey	17 Court St.
Fall River	H. S. Ramsay	27 S. Main St.
Lowell	W. E. Stanwood	Sun Bldg.
Springfield	H. G. Philbrook	95 State St.
Worcester	D. C. Daniels	State Mutual Bldg.
Michigan		
Detroit*	W. H. Clarke	Fed. Res. Bank Bldg.
Minnesota		
Minneapolis*	H. G. Timberlake	Midland Bldg.
Mississippi		
Jackson*	A. G. McIntosh	Tower Bldg.
Missouri		
St. Louis*	F. J. McDevitt	Boatmen's Bank Bldg.
Kansas City	R. W. Webb	Fed. Res. Bank Bldg.
Montana		
Helena*	R. E. Towle	Fed. Res. Bank Bldg.
Nebraska		
Omaha*	Arthur Walker	Grain Ex. Bldg.
Nevada		
Reno*	L. E. Faber	Saviers Bldg.
New Hampshire		
Manchester*	S. H. Dann	Amoskeag Industries Bldg.
New Jersey		
Newark*	R. L. Kennedy	176 Sussex Ave.
New Mexico		
Albuquerque*	George Lusk	103½ W. Central Ave.
New York		
New York*	W. O. Crabtree	Chanin Bldg.
Albany	F. J. Holman	State Bank Bldg.
Brooklyn	Emile Weinberg	16 Court St.
Buffalo	T. J. O'Rourke	Mfrs.' & Traders' Bank Bldg.
Rochester	Mahlon Gregg	Commerce Bldg.
Syracuse	T. D. Harter	Starret - Syracuse Bldg.
North Carolina		
Charlotte*	F. H. Cothran†	New Liberty Life Bldg.
North Dakota		
Bismarck*	P. W. Fawcet	1st Natl. Bank Bldg.
Ohio		
Cleveland*	Charles Terry	Union Commerce Bldg.
Cincinnati	Clifford Schulte	Union Trust Bldg.
Columbus	B. J. Zuhars	Spahr Bldg.
Dayton	Collins Wight	3rd Natl. Bank Bldg.
Toledo	H. A. Jordon	Spitzer Bldg.
Youngstown	Leiff Oyen	Union Natl. Bank Bldg.
Oklahoma		
Oklahoma City*	M. R. Harrison	Key Bldg.
Tulsa	J. H. Keys	Kennedy Bldg.
Oregon		
Portland*	J. G. Barnett	Bedell Bldg.
Pennsylvania		
Philadelphia*	O. H. Bullitt	Fed. Res. Bank Bldg.
Allentown	E. R. Follin, Jr.	506 Hamilton St.
Chester	Abbott Smith	12–14 E. 5th St.
Erie	H. B. Joyce	Erie Trust Co. Bldg.
Harrisburg	Ritchie Lawrie, Jr.	Black Stone Bldg.
Johnstown	J. S. Wagoner	U. S. Natl. Bank Bldg.
Lancaster	A. K. Barnes	Woolworth Bldg.
Norristown	Geo. Peterson, Jr.	Norristown-Penn Trust Bldg.
Pittsburgh	M. F. McOmber	Fulton Bldg.
Reading	J. A. Archer	615 Penn St.
Scranton	A. T. Snyder	1st Natl. Bank Bldg.
Wilkes-Barre	W. H. Pierce	53 W. Market St.
Williamsport	H. D. Stuempfle	Susquehanna Trust Co. Bldg.
York	R. S. Cole	Mfrs.' Assn. Bldg.
Rhode Island		
Providence*	Walker Mason	Indus. Trust Bldg.
South Carolina		
Columbia*	D. E. McDuffie	Masson Bldg.
South Dakota		
Sioux Falls	F. M. Chase	Boyce Greely Bldg.
Tennessee		
Memphis*	A. M. Field	Sterick Bldg.
Chattanooga	P. E. Shacklett	James Bldg.
Knoxville	W. W. Mynatt	Goode Bldg.
Nashville	W. G. Whitsitt	Stahlman Bldg.
Texas		
Dallas*	A. J. Langford	Fidelity Bldg.
El Paso	L. A. Wilke	El Paso Natl. Bldg.
Houston	I. M. Griffin	Fed. Res. Bank Bldg.
San Antonio	P. E. Locke	S. Tex. Bank Bldg.
Utah		
Salt Lake City*	B. W. Mendenhall	Utah Oil Bldg.
Vermont		
Montpelier*	A. M. Creighton, Jr.	12 State St.
Virginia		
Richmond*	J. L. Mason	Johnson Pub. Bldg.
Washington		
Seattle*	F. C. Bold	White Bldg.
Spokane	T. W. Weger	Old Natl. Bank Bldg.
West Virginia		
Wheeling	M. S. Sloman	Hawley Bldg.
Wisconsin		
Milwaukee*	C. E. Ives	First Wis. Natl. Bank Bldg.
Eau Claire	D. W. Walters	128½ Graham Ave.
Wyoming		
Casper*	H. C. Gustafson	P. and R. Bldg.

* Main office in state.

† Chairman, advisory committee.

together, established industrial branches in the different divisions having primary responsibility for dealing with corresponding committees of industry. Many industry committees already have been set up by the government. Committees for other industries may be established as needed. OPM has full power to take the lead in creating such groups under procedure designed to guard against violations of the antitrust law.

By organizing local "war-production associations," many factories too small to handle arms contracts, or subcontracts, can pool their facilities and jointly become a vital part of the "arsenal of democracy." Manufacturers who want to enter into such pools can learn from local OPM offices how to go about it without running afoul of antitrust laws. The first step for a manufacturer to take toward forming a production association is to get in touch with the nearest field office of the division of contract distribution of OPM, outline his intentions, and obtain detailed instructions. After this is done and a definite organization plan has been worked out, the plan should be submitted to the field office for final clearance. The procedure bars associations employing "dubious promoters" who negotiate contracts in return for a percentage of their value. This is a safeguard against abuse of the pooling plan by commission brokers.

Industrial plants seeking war production work and not having access to either of the two preceding plans should forward to the nearest field office of the contract distribution division of OPM full information regarding their equipment and products they normally manufacture. Owners of factories qualified to do war work will be given engineering assistance and directed to the government procurement offices or present contractors who have war work that they might do.

Approximately 100 field offices have been established by the OPM division of contract distribution—at least one in every state—in order to facilitate the necessary further mobilization of the country's war-production efforts. The addresses and managers of these offices are given in the accompanying tabulation.

* *Editor's Note:* As this issue went to press, OPM had been abolished and its functions taken over by the new War Production Board. Advance information indicates that the field offices will be maintained and that a division of the new Board will co-ordinate the work of the former field offices of priorities and contract distribution.

NAM President Reports on 1941 United States Production

American industry during 1941 produced as much or more essential war material than Germany and the Axis countries combined, William P. Witherow reported January 1, as he took office as President of the National Association of Manufacturers for the year 1942. This production included all the essentials for a successful military campaign: machine tools, steel, petroleum products, electric power, automobiles and trucks, airplanes, and aluminum. Mr. Witherow, President of the Blaw-Knox Corporation, Pittsburgh, Pa., indicated that his statement was a general summation of the high lights of the industrial year as they related to defense and war production.

The production of these vital wartime services and products was accomplished during one of the most critical periods in the industrial history of the United States, the report said. It was done while factories, large and small, were switching over from peacetime production to the manufacture of defense materials. It was done while industry and the government were spending upwards of $2,900,000,000 in enlarging existing plants and building new manufacturing facilities. It was done while hundreds of thousands of green workers were being taught new trades and skills.

It is not the full story of industrial production in the United States during 1941, a report that cannot be written until the war is over. Production of such vital military equipment as tanks, navy ships, ordnance, and guns, great as it has been during the past year, cannot be revealed because the information would be of value to our enemy.

POWER AND PETROLEUM

Modern industry and military forces depend heavily upon two products: electric power and petroleum. The United States is superior in the production of these two products. It leads the world in power production and the electric power companies during 1941 have made new installations that guarantee sufficient power for all the demands that will be made of the industry during the rearmament program.

The United States petroleum industry, already producing 63 per cent of the world supply of crude oil, is anticipating the demands of the defense program by installation of new and better methods. Operations have been accelerated and production expanded so that 1941 records of more than 1,404,583,000 barrels of crude oil produced and 1,412,000,000 barrels delivered to refineries will be exceeded in 1942.

In addition, the industry is enlarging its facilities to deliver oil to consumers, commercial, military, and the general public. Two hundred new and larger oil tankers, 30 delivered during the past 12 months, will be added to the tanker fleet of 300 vessels carrying American oil. Supplementing this enlarged fleet will be new pipe lines being built in the Northeastern states and in the South.

Production of 100-octane-rating gasoline for airplane consumption has increased during 1941 to approximately 45,000 barrels daily, and will reach an estimated 120,000 barrels daily within the next several months.

MACHINE TOOLS

The past year has seen the production of machine tools, without which no rearmament campaign could be conducted, reach an all-time record. The industry, once described as one of the so-called "bottlenecks" of the defense drive, produced approximately 200,000 units during the past year, 100 per cent more than were produced in 1940 and eight times the normal annual production of the industry over the past ten years.

The average machine tool manufactured since January 1940 is three times more productive than the average machine tool in use a year ago. Hence, the industry has made an equivalent of 600,000 units during 1941 in comparison with machines made prior to 1940.

AIRCRAFT

The American aircraft industry has achieved during the past year the annual output of German warplanes.

ALUMINUM

The demand of the rearmament program for aluminum has been great. It is one of the basic materials used in building airplanes and is widely used for scores of other war and defense purposes. To meet this demand the industry has expended during 1941 upwards of $215,000,000 for new facilities, and the combined production of the United States and Canada at the end of the year reached a volume of 1,120,000,000 pounds per year. The United States Bureau of Mines has estimated the combined aluminum production of Germany, Italy, and all the conquered countries was slightly over 1,000,000,000 pounds in the corresponding period.

AUTOMOBILES AND TANKS

The Office of Production Management reported in December that "about half of the total man-hours worked in automobile assembly and parts plants are being devoted to wartime production," a 50 per cent increase in defense production in the same plants during September and October. The statement added that temporary year-end idleness of workers caused by the curtailment of automobile manufacturing will be short because the industry is swinging into wartime production quickly.

The industry's investment in war and defense plants plus $484,000,000 of government funds invested in new facilities for the making of war materials produces every form of military equipment. Tanks are rolling off the assembly line of the Chrysler Corporation at a figure exceeding early estimates, and other manufacturers are retooling their plants to build tanks during 1942. Three of the industry's plants were retooled during the past year and are now building bomber and fighter-plane

engines, and elsewhere automobile and truck plants are making ordnance, shells, bomb fuses, recoil mechanisms, percussion caps, casings, and subassemblies for aircraft plants.

In addition, the industry during 1941 opened training schools for new employes and for enlisted men and officers of the Army, Navy and Air Corps. The Ford Motor Company's River Rouge school trained 4,500 newly enlisted men as skilled mechanics for the Army and Navy and another 2,000 were taught the various skills required for maintenance of airplane engines. The same company has instructed 120 officers per month during the past year in the operation and maintenance of motorized equipment and mobile classrooms have been sent by the industry to Army camps to instruct men in the field on motor-equipment operations.

EMPLOYMENT AND EXPANSION

Another gauge by which the war-production program can be judged is employment at industrial plants during the past year and a comparison of present payrolls with past years. The increase has been large in all industries contributing to the war program, the aircraft industry showing during 1941 the largest gain. Between June 1940, and July 1941, the aircraft industry's payrolls increased 152 per cent, and indications are that the percentage has been greater during the last several months. Shipyards of the nation in the same period increased their payrolls from 159,400 to 348,000 men, an increase of 188 per cent, and plants making ordnance in the same period have added 71 per cent to their payrolls. The average increase of employment at war and defense plants is approximately 60 per cent.

Meantime, the plant-expansion program is nearly complete. OPM's estimate that plant expansions and new plants built during the national emergency and through last September cost $2,900,000,000 does not take into consideration the amount of money invested by manufacturers who did not have to secure a "certificate of necessity" from Washington. This building has been large because many companies had materials available for new building and did not need aid from the administration to get priority on materials.

The expansion has involved 3,004 plants in various parts of the country and included 632 machinery manufacturers, 444 plants making iron and steel, and 24 plants making petroleum and coal products.

Erie Conservation Plan Endorsed

A comprehensive plan of industrial conservation designed to secure the active cooperation of industry in the economic use of raw materials and the salvaging of scrap needed for America's war industries is now operating in Erie, Pa., according to a recent report from the Office of Production Management.

The program was worked out by leading manufacturing interests of Erie, with the full endorsement of the Bureau of Industrial Conservation of the OPM. According to officials of the Bureau, extensive savings in the use of raw materials have already been effected, although the plan has been in operation less than three weeks. The industrial salvage section of the Bureau will sponsor the inauguration of similar programs in 30-odd centers in the course of the next few months.

The Erie program was formally launched on December 12, when leading executives of the city's large and small industries and trade and business associations attended an organization meeting and set up an executive committee. This committee is composed of the following:

F. E. Bliven, General Electric Company, *chairman*; R. G. MacElroy, secretary, United States Metals Products Company; M. F. McCarty, Erie Forge and Steel Company; Harry Bole, president, Erie Foremen's Association; and Dana Jones, secretary of the Manufacturers Association of Erie.

The executive committee then selected a subexecutive committee, composed of executives engaged in the manufacture of products generating such salvageable materials as iron and steel scrap, nonferous scrap (brass, copper, aluminum, lead, and zinc), waste paper, scrap rubber, cotton and woolen rags, and miscellaneous products. The following program of objectives was developed:

Wrecking of abandoned and obsolete machinery and equipment.

Utilization of all critical materials to the best advantage.

Minimization of waste and spoilage.

Reuse, wherever possible, of blanks, cut-downs, short ends, clippings, etc.

Selective handling and segregation of scrap and overage at the source.

Avoidance of contamination.

Speeding the return of scrap and waste materials through existing channels to mills and refineries.

To carry out these objectives the committees recommended the following salvage procedure and methods:

A. Arrange in every plant for the appointment of a "Salvage Department Manager", or for the delegation of some one individual in each plant to be responsible for the wrecking of obsolete machinery, equipment, etc.

B. Arrange to train men, if necessary, in the definition of scrap, its nature, its handling and its salvage.

C. Arrange for a system of periodic reports (weekly reports were considered best during the early stages of the campaign) on scrap collected to be made by every plant to the executive committee.

Under the operation of the plan, the individual "salvage managers" in the various plants designate their own plant and

**Editor's Note:* As this issue went to press, OPM had been abolished and its functions taken over by the new War Production Board.

Bendix Plant Uses Automatic Furnaces

Westinghouse photo

Diversified electric furnaces with automatically controlled atmospheres are used in the Eclipse Division of the Bendix Aviation Corporation to speed production and maintain uniform quality in heat-treated parts for airplane accessories. Shown here is a 68-kw pit furnace used for "batch tempering", with a 36- by 36-inch deck basket of parts being lowered into the furnace. The precision heat-treating cycle includes recirculation of hot gas through cooler to cool the charge before removal from the furnace. Production averages 1,000 to 1,200 pounds every four hours.

departmental salvage committees and work out their own system of handling, reporting, etc., as well as methods to be followed in wrecking obsolete machinery, disposing of out-of-date or discontinued finished products and other stored materials not likely to be used.

Salvage managers of the different plants are also arranging joint meetings to report on their work and to exchange information.

Since the success of a salvage program depends upon the co-operation of the man at the machine, the salvage managers agreed upon a three-point program to be brought to the attention of every employee, urging him to:

1. Conserve materials; minimize waste and spoilage.

2. Sort blanks, short ends, cut-downs, clippings, etc., with a view to their reuse either in his department or plant or by some other department or plant in the district.

3. Separate unavoidable scrap and cut-downs at the source; avoid contamination.

In order that other manufacturers may benefit from the experiences gained in the plan, the executive committee will enlist the support of local manufacturing, production, and trade associations. The committee will also assemble and keep all records of scrap collected and salvaged by all plants and evaluate the complete record in a report to the OPM.

The committee will designate a member to act as liaison contact with the industrial salvage section of the Bureau of Industrial Conservation. The salvage section has offered to make available the services of an experienced salvage engineer for consultation on specific problems, to supply speakers and salvage consultants for important meetings, and to serve as a clearing house for information.

Stevens Institute Offers Women Emergency Engineering Training

An emergency training course in engineering at the college level to fit college women for technical positions in war industries seriously short of engineering personnel has been announced by the War Industries Training School of Stevens Institute of Technology.

College women with previous training in mathematics, physics, and chemistry will be admitted to a full-time pre-employment course, "Introduction to Engineering," beginning on February 2, 1942, and continuing for 12 weeks. The course is a part of the engineering defense training program of the United States Office of Education. Tuition is free to acceptable applicants. The course will include engineering problems (an application of mathematics and physics to engineering), engineering drawing, and machine-shop practice. It will qualify women for such positions as draftsmen, inspectors, supervisors of women operatives, engine testing, computation, and a wide range of precision work for which many women have special aptitudes.

While courses training women as machine operatives, bench workers, and the like are available elsewhere, the Stevens course is believed to be the first intended to enable college women with a flair for science to make the fullest possible use of their ability and training in the tremendous work of armament-production that confronts the nation.

To counsel the college in inaugurating and developing this pioneer training course for women and to deal with the various problems of adjusting women to their new role in industry, an advisory committee has been appointed, which includes the following:

Margaret T. Corwin, dean, New Jersey College for Women; Virginia Gildersleeve, dean, Barnard College; Mrs. Eleanor H. Grady, dean, Hunter College; Constanse Warren, president, Sarah Lawrence College; Emily Burr, director, Vocational Adjustment Bureau for Girls, New York, and Doctor Lillian Gilbreth, Bloomfield, N. J., engineer and member of the engineering faculties of Purdue University and Newark College of Engineering.

Committee on Wartime Personnel Appointed

The formation of a special committee on wartime requirements for specialized personnel was recently announced by the National Resources Planning Board, Washington, D. C. Leonard Carmichael, director of the National Roster of Scientific and Specialized Personnel (see *EE, Aug. '41, p. 413*) is chairman of the new committee, which operates as part of the Roster.

The committee will make recommendations with regard to the problems created by the heavy drain on specialized personnel through the demands of the Army, Navy, and war industries. An increasing number of specialists have been called from colleges and technical schools with a resultant decrease in the number of available teachers, professors, and research associates.

The personnel of the committee is:

Leonard Carmichael, chairman

J. C. O'Brien, executive officer

E. C. Elliott, president, Purdue University

M. B. Folsom, treasurer, Eastman Kodak Company

G. S. Ford, former president, University of Minnesota

Brigadier General Lewis B. Hershey, director, selective service system

E.F. McGrady, special adviser to the Secretary of War

Monseigneur J. A. Ryan, National Catholic Welfare Council

J. W. Studebaker, commissioner of education, Federal Security Agency

B. M. Woods, University of California

Owen D. Young, honorary member, board of directors, General Electric Company

Planning Board Reports Progress

A Progress Report for the two-year period ending June 30, 1941, has been issued by the National Resources Planning Board. In addition to progress in the organization and achievements of city, state, regional, and national planning agencies under the leadership of the board, and long-term studies of United States resources and economy, the report also describes planning activities in relation to national defense. Among the latter are the preparation of the Roster of Scientific and Specialized Personnel (see *EE, Aug. '41, p. 413–14*); aid to communities in planning facilities around training camps or defense-industry concentrations; collection of data for use in locating defense industrial plants; and development of plans to prevent industrial collapse in the post-emergency period. Copies of the report may be obtained from the Superintendent of Documents, Washington, D. C., at 25 cents each.

Positions to Be Filled Through Civil Service Examination

Notice of the following positions, which will be filled through civil service examinations, is published here as a service to members of the Institute. Application forms and full information as to requirements for examinations may be obtained from the secretary of the Board of United States Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D.C.

Defense Production Inspectors. Defense Production Protective Service, War Department. Salaries range from $2,600 to $5,600 a year. Applications will be rated as soon as possible after receipt at the U. S. Civil Service Commission, Washington, D. C. Inspectors will be responsible for making recommendations to prevent interruptions or delays in the production and delivery of all types of defense material when these interruptions may be caused by major accidents, explosion or other hazards inherent in manufacturing plants. No written test will be given. Applicants will be rated on their education, experience, and personal qualifications. The requirements are as follows:

(a) General experience in performing inspectional and professional engineering advisory services for manufacturers, as inspector in a property insurance rating bureau, as plant protection supervisor or master mechanic in a large industrial establishment, or as professional engineer specializing in plant protection work.

(b) Chief and principal inspectors ($5,600 and $4,600 a year) are also required to have had responsible administrative experience not necessarily in connection with plant protection inspections.

Provision is made for substituting appropriate college study for part of the prescribed experience. Although applications will be accepted until further notice, qualified persons are urged to apply at once.

Engineer to Direct West Point

Major General Francis B. Wilby, commander of the First Corps Area United States Engineers, Boston, Mass., has been appointed by the War Department as superintendent of the United States Military Academy, West Point, N. Y., succeeding Major General Robert L. Eichelberger, who has been assigned to command a combat division.

General Wilby was educated at Harvard University and at the United States Military Academy. After graduating from the Army Engineer School, he served in Cuba, the Philippine Islands, and China and fol-

lowing service as director of the First Corps Engineers School, he went to France in 1917. Later as assistant in charge of engineering in the office of the chief of engineers, he was appointed to command the First Engineer Regiment, First Division, Corps of Engineers, National Army, with the rank of colonel. Following World War I, he returned to the grade of major, and after graduating from the General Staff School, was a member of the War Department General Staff 1924–28. He later was made division engineer of the North Atlantic Division, New York, N. Y., and in 1939 was appointed chief of staff of the First Army.

Free Radio Engineering Training. A course in radio engineering, sponsored by the University of Maryland, College Park, under its engineering defense training program in co-operation with the United States Office of Education, started January 5, 1942 and will continue until August 7, 1942. A full-time day course including training in advanced theory and practical radio engineering it was open, without tuition, to applicants presenting a degree in electrical engineering from a recognized college or university.

INDUSTRY

Research by Business Surveyed

Recently issued as the third of the series of reports by the National Resources Planning Board on "Research—a National Resource" is "Business Research." The two previous reports covered the "Relation of the Federal Government to Research," including a study of academic research, and "Industrial Research" (*EE, July, '41, pages 360–1*). Taken together the three reports present "an over-all, though not a complete, view of the amazing extent and variety of research in the United States, measured in financial terms by an annual expenditure of several hundred million dollars".

The report on "Business Research," described as a pioneer attempt to evaluate social-science research in that field, surveyed, for 33 firms of varying types, the business research work, methods, facilities and organization, application of results, dissemination of information, and opportunities for research personnel. Noting that the report on industrial research dealt chiefly with research in the natural sciences, the present report points out that many other types of business research are important for business, for social analysis, and for national productivity. Cited as fields in which notable results are being obtained are personnel, scientific management, operational analysis, administrative organization and processes, accounting and cost accounting analysis of vital statistics, industrial relations, marketing.

The report was prepared under the direction of a special subcommittee of the science committee of the National Resources Planning Board. Members of the subcommittee, which was appointed by the Social Science Research Council, are E. G. Nourse, *chairman*, E. B. Wilson, and Willard L. Thorp; among the group of advisers appointed by the Business Advisory Council, United States Department of Commerce, is Morris E. Leeds (F'26), chairman, board of directors, Leeds and Northrup Company.

Planning Board Sets Up Puerto Rico Office. A regional office of the National Resources Planning Board has been established at San Juan, Puerto Rico, to serve as a clearing house for programs for the development of that territory, according to recent announcement. Officials and consultants of the Planning Board office will work with the governor of the territory and such agencies as he may designate. A regional office was also established in Alaska recently (*EE, Oct. '41, p. 513*).

FPC Licenses Tacoma Project

A 50-year license has been issued by the Federal Power Commission to the City of Tacoma, Wash., for the construction, operation, and maintenance of a 156,000-horsepower hydroelectric project on the Nisquelly River in Thurston, Pierce, and Lewis counties, affecting lands of the United States within the Snoqualmie National Forest, according to FPC announcement.

The project will consist of two developments, one upstream and one downstream. The former will include a 300-foot concrete arch dam, to be known as Alder Dam; a storage reservoir of about 147,000 acre-feet usable capacity; a powerhouse of 69,000 horsepower installed capacity; a switchyard; and a 110-kv transmission line extending to the switchyard of the downstream development, which development will consist of a 200-foot concrete gravity diversion dam, to be known as LaGrande Dam; a regulating reservoir of about 10,000 acre-feet capacity; a 6,500-foot concrete-lined tunnel, 14½ feet in diameter; a powerhouse of 87,000 horsepower; and a 110-kv transmission line extending about 34 miles to the Tideflats substation at Tacoma.

New Executives Elected by Allis-Chalmers. The board of directors of Allis-Chalmers Manufacturing Company, Milwaukee, Wis., recently elected Max W. Babb, formerly president of the company, chairman of the board, and W. C. Buchanan, director and executive committee member, president of the company. Mr. Babb joined the Allis-Chalmers Company, predecessor of the present organization, as its attorney in 1904. He was vice-president from 1913 to 1932, when he became president. The position of chairman of the board which he now occupies has been vacant since the death of General Otto H. Falk in 1940. Mr. Buchanan has been associated with the steel industry since 1904, when he was employed by the Cambria Steel Company in Johnstown, Pa., and has occupied managerial positions with various

New Bell Laboratories Building Occupied

Work is now in progress in the new laboratory of the Bell Telephone Laboratories at Murray Hill, N. J. First group to occupy the new laboratory consisted of 140 members of the outside-plant development department. Other groups that have been or are scheduled to be transferred to the new laboratory are: metallurgical, station-apparatus development, physical research, circuit research, and chemical. This view shows the main group of buildings; the restaurant and clubrooms are in the low structure in the left foreground.

companies. Since 1935 he has been president of the Globe Steel Tubes Company, Milwaukee, and will continue to hold that position.

Ninth Major Generator at Boulder Dam. When the ninth 82,500-kw generator at the Boulder Dam powerhouse recently went into operation, the station's installed capacity reached 787,000 kw, making it reputedly the largest generating station in the world. Nine major units, one 40,000-kw generator, and two 4,800-kw station generators have now been installed; two more large units are in process of installation. Ultimate capacity of the plant is expected to be 1,322,000 kw. The new machine is the third major unit to be installed in the Arizona side of the powerhouse; six are already in service on the Nevada side.

Manly Elected FPC Vice-Chairman. Commissioner Basil Manly has been elected vice-chairman of the Federal Power Commission for the coming year, succeeding Commissioner Claude L. Draper. Mr. Manly has been a member of the Commission since 1933, and was previously vice-chairman from 1933 to 1936. He served as commissioner-in-charge of the National Power Survey and Electric Rate Survey in 1933–36, as vice-chairman of the National Defense Power Committee in 1938, and as chairman of the committee on generation and distribution, National Association of the Railroad and Utilities Commissioners, in 1939.

Brown Boveri 50th Anniversary. Brown, Boveri and Company, Ltd., Baden, Switzerland, celebrated its first 50 years of existence on October 2, 1941. The firm, founded in 1891 by Charles Brown and Walter Boveri, was incorporated in that year and in 1892 began production of electrical machinery and apparatus. The company, which now has branches in several European countries, has made many important contributions to the field of electrotechnics and thermodynamics.

HONORS

Washington Award for 1942 to Be Presented to W. L. Abbott

William Lamont Abbott (F'13) retired chief operating engineer of the Commonwealth Edison Company, Chicago, Ill., has been selected to receive the Washington Award for 1942. A biographical sketch of Doctor Abbott appears on pages 93–4.

Awarded annually to an outstanding engineer, "in recognition of pre-eminent service in advancing human progress," the Washington Award is conferred by a commission representing the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, AIEE, and the Western Society of Engineers. It was founded in 1916. Doctor Abbott is the ninth AIEE member to receive this honor. Presentation of the award will be made at a meeting of the participating societies at Chicago, Ill., February 26, 1942.

OTHER SOCIETIES

AIME 1942 Officers Elected

Election of officers for 1942 was recently announced by the American Institute of Mining and Metallurgical Engineers. They are:

President—Eugene McAuliffe, president, Union Pacific Coal Company, Omaha, Nebr.

Vice-presidents—Chester A. Fulton, president, Southern Phosphate Corporation, Baltimore, Md., and L. E. Young, consulting mining engineer, Pittsburgh, Pa.

Newly elected directors—Wilbur Judson, vice-president, Texas Gulf Sulphur Company, New York, N. Y.; Leo F. Reinartz, manager, American Rolling Mill Company, Middletown, Ohio.

Re-elected directors—Charles Camsell, deputy minister, Department of Mines and Resources, Ottawa, Ont.; C. A. Garner, vice-president, Jeddo-Highland Coal Company, Jeddo, Pa.; William B. Heroy, president, Pilgrim Exploration Company, Houston, Tex.; Francis A. Thompson, president, Montana School of Mines, Butte.

Future Meetings of Other Societies

American Chemical Society. April 20–24, 1942, Memphis, Tenn.

American Institute of Chemical Engineers. 34th semiannual meeting, May 11–13, 1942, Boston, Mass.

American Physical Society. 247th meeting, February 20–21, 1942, Detroit, Mich.

American Railway Engineering Association. Annual convention, March 17–19, 1942, Chicago, Ill.

American Society for Testing Materials. Spring meeting, March 2–6, 1942, Cleveland, Ohio.

American Society of Mechanical Engineers. Spring meeting, March 23–25, 1942, Houston, Tex.

Greater New York Safety Council. Convention and Exposition, March 3–6, 1942, New York, N. Y.

National Electrical Manufacturers Association. Midwinter meeting, February 16–20, 1942, Chicago, Ill.

National Fire Protection Association. May 11–15, 1942, Atlantic City, N. J.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Graphical Aid in Multiplying and Dividing Complex Numbers

To the Editor:

The following description of a graphical aid in the multiplication and division of complex numbers may prove useful to engineers having to do a considerable number of such calculations. As may be seen from Figure 1, the chart is constructed by plotting upon ordinary cross-section paper angles from 0 to 360 degrees, and a number of circles, the radii of which are the numbers having logarithms of 0.1, 0.2, 0.3, and so on. As many subdivisions of the angles and logarithmic circles may be drawn as are necessary to obtain the desired accuracy.

The operation of this chart depends upon the elementary rule for the multiplication of complex numbers, namely: the scalar value of the product of two complex num-

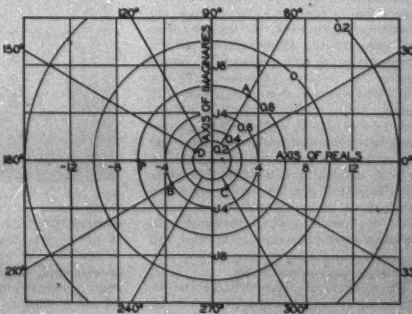

Figure 1. Graphical aid for multiplication and division of complex numbers

bers is the product of the individual scalar values, and the angle of the product is the sum of the individual angles. This may be written:

$$(a'+ja'')(b'+jb'') = AB/\varphi_a+\varphi_b = \log^{-1}(\log A + \log B)/\varphi_b+\varphi_b$$

By plotting $a'+ja''$ and $b'+jb''$ upon the chart, the angles ϕ_a and ϕ_b may be read directly and log A and log B determined by reading the mantissas from the circles and prefixing the proper characteristics. The product may then be found by plotting on the chart the sum of the angles and the mantissa of the sum of the logarithms. The rectangular co-ordinates at this point represent the product, with the decimal point being determined by the characteristic of the sum of the logarithms. Division would be the reverse of this process.

A numerical example will illustrate the process further. Let it be desired to find the value of

$$p'+jp'' = P/\varphi_p = \frac{(a'+ja'')(b'+jb'')}{(c'+jc'')(d'+jd'')}$$

where

$a'+ja'' = A/\varphi_a = 3{,}160+j5{,}460$

$b'+jb'' = B/\varphi_b = -34.4-j20$

$c'+jc'' = C/\varphi_c = 1{,}280-j2{,}180$

$d'+jd'' = D/\varphi_d = -13.8+j8$

By plotting these values on the chart it is found that:

$\log A = 3.8$	$\varphi_a = 60°$
$\log B = 1.6$	$\varphi_b = 210°$
$\log C = 3.4$	$\varphi_c = 300°$
$\log D = 1.2$	$\varphi_d = 150°$

The value of P is then found by carrying out the following calculations:

$$\log P = (\log A + \log B) - (\log C + \log D) = (3.8+1.6) - (3.4+1.2) = 0.8$$

$$\varphi_p = (\varphi_a+\varphi_b) - (\varphi_c+\varphi_d) = (60°+210°) - (300°+150°) = -180°$$

On the chart the rectangular co-ordinates at -180 degrees (φ_p) and 0.8 (mantissa of log P) are $-6.3+j0$. Since the characteristic of log P is zero, this is the desired value of $p'+jp''$.

It is necessary to construct the chart for only one quadrant instead of for the full 360 degrees as shown, if proper account is kept of the signs of complex numbers in the other three quadrants.

J. M. BARRY (A'27)

(Electrical-engineering department, Pennsylvania Water and Power Company, Baltimore, Md.)

Industrial and Cultural Japan

To the Editor:

In view of the present situation in the world, it might be interesting to look up and read at least the last part of my article, published in *Electrical Engineering* for February 1937, pages 208–15, entitled "Industrial and Cultural Japan." The Japanese failed to maintain "self-restraint and good sense," and now there is trouble.

DUGALD C. JACKSON (F'12)

(Professor emeritus of electrical engineering, Massachusetts Institute of Technology, Cambridge)

Dielectric Nomenclature

To the Editor:

Standardization of symbols and nomenclature is desirable wherever possible so that workers in a particular field may be exactly understood by one another and also so that casual readers may find the least possible confusion in attempting to understand papers by different authors on similar subjects.

In choosing a quantity through which it is desired to interpret experimental results, there are three considerations of major importance:

1. The possible physical meaning or interpretation of that quantity in terms of known physical laws
2. No ambiguity as to definition or meaning
3. Elimination as far as possible of other physical quantities which vary with the experimental parameters being studied

To meet these requirements the General Electric Company's research laboratory has been using for over 10 years in discussion and in published papers the following system of nomenclature and definitions for

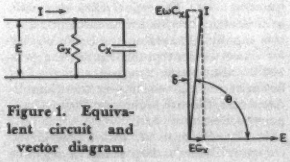

Figure 1. Equivalent circuit and vector diagram

dielectric constant, loss factor, and power factor, in interpreting the properties of all classes of dielectrics at all frequencies and temperatures.

Admittance

$$Z^{-1} = G_x+j\omega C_x = \omega C_y(\epsilon''+j\epsilon') \quad (1)$$

Dielectric constant

$$\epsilon' = (C_x/C_y) \quad (2)$$

Loss factor

$$\epsilon'' = (G_x/\omega C_y) = 1.8\times10^{12}\gamma/f \quad (3)$$

$$\tan\delta = (G_x/\omega C_x) = (\epsilon''/\epsilon') \quad (4)$$

Power factor

$$PF = \cos\theta = \sin\delta = \cos\cot^{-1}(\epsilon''/\epsilon') \quad (5)$$

Watts dissipated

$$W = E^2G_x = E^2\omega C_y\epsilon'' = 0.555\times10^{-12}E^2f\epsilon''(a/l) \quad (6)$$

Watts per unit volume

$$W' = (E^2G_x/al) = 0.555\times10^{-12}f\epsilon''(E^2/l^2) = \gamma(E^2/l^2) \quad (7)$$

where

E = magnitude of sinusoidal applied voltage

I = magnitude of sinusoidal current

G_x = equivalent parallel conductance of the unknown

C_x = equivalent parallel capacitance of the unknown

$\omega = 2\pi$ (frequency in cycles per second)

$j = \sqrt{-1}$

C_y = vacuum (or air) capacitance of same size and shape as unknown = $8.842\times10^{-14}\times a$ (sq. cm. area)/l(cm. length) farads

γ = equivalent parallel conductivity in ohm^{-1}cm^{-1} = $G_x(l/a)$

θ = phase angle

$\delta = (90-\theta)$ = loss angle

This system is being advocated again at this time because some European and American writers are applying the name "loss factor" to the quantity tan δ. This practice appears to me to be very unfortunate and I urge its abandonment for the following reasons:

1. The definitions given here correspond with those defined in the final revised report of the American Standards Association Sectional Committee on Definitions of Electrical Terms—C42, July 1937, as follows:

Dielectric constant	05.30.050
Loss factor	05.30.100
Dielectric phase angle (θ)	05.30.090
Dielectric loss angle (δ)	05.30.095

2. *Dielectric constant* is the generally accepted measure of energy which is recoverably stored. It is independent of the amount of energy which is dissipated as heat.

3. *Loss factor* according to the ASA definition is the measure of energy dissipated as heat independent of the amount of energy stored.

4. By separating the loss and capacitance components and studying the variations of their coefficients with experimental parameters such as frequency and temperature, a better physical concept of the behavior of complex dielectrics is obtained.

5. Calorimetric methods have been used to measure the losses in insulating materials at high voltage and high frequency. Equation 7 shows that the loss factor of the material by the ASA definition is directly proportional to the watts dissipated per unit volume, per unit voltage gradient, per cycle. The dielectric constant often is not known in calorimetric measurements but it need not be known if the loss factor is defined according to equation 3.

The symbols used here are not necessarily the most appropriate. The selection of symbols must necessarily be a compromise which should be made by appropriate "standards" committees of various organizations concerned. The important point

of this discussion is that the name "loss factor" should be applied to a coefficient which represents energy dissipated only and not to a quantity which is the ratio of energy dissipated to energy stored. In addition it is very desirable that it be used in agreement with the present ASA Definitions of Electrical Terms, *C*-42.

HUBERT H. RACE (F'39)
Research engineer, General Electric Company, Schenectady, N. Y.)

Progress in Relaying

To the Editor:

In the December 1941 issue of *Electrical Engineering* appeared an interesting account of relay developments which took place during the last ten years.

The following notes, concerning the earlier pioneering history of relay developments, also may be of interest to many engineers.

Previous to the year 1901, protective relays were not in very extensive use and were considered unreliable and complicated. Power directional relays were unknown and time elements were either of the bellows type or consisted of clockwork mechanisms. The electrical elements were not of the sensitive, instrument-like nature, but were generally of the solenoid type, or combinations of trip coils on the breakers.

The desire for reverse-power detection and protection necessitated the use of instrument movements. The first of these was an adaptation of the induction-type indicating wattmeter made by adding front and back adjustable contacts. This was designed by Doctor Frank Conrad for the Westinghouse Electric and Manufacturing Company in 1901. Like the wattmeters, it had aluminum drum movements and was made both as single-phase units and in a polyphase form. It was instantaneous, in that no time-delay action was introduced. It was first described in an early Westinghouse catalog (number 300, dated 1902).

In 1906 a relay was designed to supersede the preceding. We called it the "a-c overload and reverse current relay." It used disks, magnets, and electromagnet punchings from an early form of watt-hour meter, but the windings acted as a peculiar combination of ammeter and voltmeter torques in which the voltage biased or polarized the torque so that it took less current to trip in the reverse direction than in the normal direction. When the voltage got low, it became an ordinary overcurrent relay. The first publication was in an early issue of a catalog dated October 1913, in which it was called the "type *C* overload and reverse-current relay."

This relay was designed by the writer, who was at that time Conrad's assistant. The writer first suggested the use of a watt-hour disk movement so as to give an inverse time element with magnetic damping. The electrical scheme, however, is so characteristic of Conrad's way of thinking that I presume it must have been suggested by him during the course of the development of this type *C* relay. We also made the type *C* relay as a straight overload relay, wound for amperes only.

The scheme of the type *C* relay was surely a step forward both as an accurate time element and as a "reverse current" relay. But as transmission-line short circuits often dropped the voltage to very low values, the problem of reverse power selective protection was far from solved by this relay.

At this point, R. D. Mershon came into the picture with schemes for a solution involving a moving-coil voltage-regulating transformer, and phase-shifting device, etc., all intended to keep the voltage and the phase angle from shifting when short circuits occurred. He made arrangements that we should develop this and the work progressed in 1905 and 1907, the writer being given the job of working it out. The complications became so great as to make the scheme impractical. This led me to break down the entire problem by a very simple solution, which was the use of a floating watt-operated contact in series with the overload contacts to prevent tripping when the power direction remained normal. It worked very well, even down to five per cent voltage and at badly lagging power factors. This was the MacGahan patent number 977,649, filed 1908. We thereupon discontinued the Mershon experiments. An article in the *Electric Journal*, September 1915, page 417, by Paul MacGahan and B. H. Smith is a good record of the situation to that time.

An improved arrangement was covered by MacGahan patent number 1,314,825, issued in 1919. The type *C* relay, also made as a straight overload time-element relay, was rapidly superseding the bellows relay for excess current protection by the year 1912. Many large companies adopted it, foremost among which was the Consolidated Gas, Electric Light, and Power Company of Baltimore, Md.

F. E. Ricketts of the Consolidated company made a deep study of selective protection problems, and may be said to be the "father of selective relay protection." He early realized the shortcomings as well as the basic advantages of the induction relay and invented a "compensating coil" to overcome the remaining disadvantages. This later became known as the torque compensator. It was described in Mr. Ricketts' article, "The Protection of Transmission Circuits for Relays" which appeared in the *Electric Journal*, April 1914. The scheme was disclosed in Mr. Ricketts' patent number 1,286,415 which was acquired by the Westinghouse company.

The next step in protective relay development was due to B. H. Smith (patent number 1,286,239) who showed in 1914 how the Ricketts torque-compensator scheme could be applied to the pole-piece windings of an induction relay. The result was the well-known type *CO* relay.

PAUL MAC GAHAN (M'15)
(Development engineer, meter department, Westinghouse Electric and Manufacturing Company, Newark, N. J.)

Characteristics of Driven Grounds

To the Editor:

The paper by P. L. Bellaschi on "Impulse and 60-Cycle Characteristics of Driven Grounds," which appears in the AIEE *Transactions*, volume 60, 1941 (March section), pages 123–8, is of considerable interest. It unfortunately came to my attention too late to permit me to submit a written discussion. Since certain of my thoughts regarding the subject were not covered in the discussion and closure appearing at page 717 of the same volume, I am taking this opportunity to set them forth.

One point of particular interest in Mr. Bellaschi's paper is the residual oscillatory voltage and current in oscillogram *AF* of his Figure 3. This is to be expected. A ground rod is essentially an imperfect capacitor in series with an inductance and a resistance. This results from the fact that the earth is a semiconducting substance and the ground resistance is composed of two elements; the contact resistance of the rod with the earth and the leakage resistance of the earth itself. These two components of the resistance are in series and the contact resistance is shunted by the capacitance of the rod to ground.

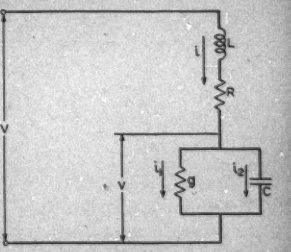

Figure 1

Since the imperfect capacitor may be treated as a perfect capacitor shunted by a conductance, the equivalent circuit of a ground rod is represented by Figure 1 of this letter where:

R = the leakage resistance of the soil
L = the inductance of the ground rod
g = the conductance of the rod to earth
C = the capacitance to earth of the ground rod

Let the operation d/dt be denoted by D. If v = the voltage drop across the contact resistance, then

$$v = V - Ri - LDi \qquad (1)$$

And

$$i = CDv + gv \qquad (2)$$

Differentiating equation 1 gives

$$Dv = DV - RDi - LD^2i \qquad (3)$$

Substituting equations 3 and 1 in equation 2 and combining terms

$$CLD^2i+(CR+gL)Di+(1+gR)i= CDV+gV \quad (4)$$

Let

$$^1/_2(R/L+g/C)=n \quad (5)$$

And

$$(1+gR)/CL=m \quad (6)$$

By substituting equations 5 and 6 in equation 4 we have:

$$D^2i+2nDi+mi=\frac{1}{L}DV+\frac{gV}{CL} \quad (7)$$

Where the voltage V is a surge or lightning discharge it may be represented by the general equation:

$$V=E(\epsilon^{-at}-\epsilon^{-bt}) \quad (8)$$

By differentiation

$$DV=E(b\epsilon^{-bt}-a\epsilon^{-at}) \quad (9)$$

Substituting equations 8 and 9 in equation 7 and combining terms gives:

$$D^2i+2nDi+mi= \frac{E}{L}[(b-g/C)\epsilon^{-bt}-(a-g/C)\epsilon^{-at}] \quad (10)$$

The solution of equation 10 is of the form

$$=A\epsilon^{ht}+B\epsilon^{kt}+\frac{\epsilon^{a't}}{F(a')} \quad (11)$$

where

$$h=-n+(n^2-m)^{1/2} \quad (12)$$

$$k=-n-(n^2-m)^{1/2} \quad (13)$$

For the purpose of this letter it is unnecessary to solve for the arbitrary constants A and B or to evaluate the particular integral $\epsilon^{a't}/F(a')$. It is obvious that where the roots h and k are conjugate and complex the solution of equation 10 will result in an oscillatory wave. This substantiates the condition obtained by the author in oscillogram AF. The extent and duration of the oscillations would depend on the values of R, g, L, and C.

In presenting and analyzing the results of his experiments, Mr. Bellaschi neglects the effect of the capacitance of the ground rod. This effect is important, for the capacitance is usually large. Under transient conditions of the surge the capacitance effectively shunts out the contact resistance and the resistance measured is essentially the leakage resistance of the earth itself. This is not the case when d-c or 60-cycle measurements are made. The ohmic values obtained under such circumstances include the sum of the contact and leakage resistance.

The foregoing point has some possibilities worthy of further pursuit. First it suggests that, neglecting the fact that nonhomogeneous materials do not obey Ohm's law, no relation between the ratio of impulse to 60-cycle impedance and the crest current is to be anticipated. This could be substantiated by conducting measurements on several ground rods of different diameters, using values of crest currents for each to give equal voltage gradients on each rod. Under these circumstances the curve expressed by Figure 4 of Mr. Bellaschi's paper should be essentially a horizontal line.

The relation between the capacitance and contact resistance suggests further that the d-c or 60-cycle resistance is one of essential importance, insofar as it indicates the magnitude of the soil's leakage resistance. Protection of electrical systems from lightning and artificially induced surges is the primary purpose of grounding. If the contact resistance is effectively shunted out by the capacitance under the transient conditions imposed by the surge, the leakage resistance becomes of primary importance to us. A means of determining the magnitude of, and the relation between, the contact resistance, the leakage resistance, and the capacitance is required by the industry. This might be accomplished by means of high-frequency tests using low current values. As the frequency increases the impedance of the ground rod will be found to decrease, because the capacitance will shunt out the contact resistance. From tests of this nature, considerable valuable data on the contact resistance, leakage resistance, and capacitance could be compiled for different types of soils.

The need for the evaluation of the various soil constants is great. Data on this subject will be of assistance in determining size, number, and length of ground rods required to obtain the desired degree of protection.

It is essential to keep in mind that the contact resistance is reduced by paralleling rods while the leakage resistance is not correspondingly reduced. Therefore, we find that parallel rods do not follow the reciprocal law of parallel resistances. This explains why Mr. Bellaschi finds the ratio of the impulse to 60-cycle impedance for parallel rods is not as low as the corresponding ratio for the individual rods.

Generally speaking, the leakage resistance will be reduced more effectively by driving rods to greater depths rather than by paralleling. The contact resistance may be increased by deep grounding. However, as previously stated, we are interested in reducing the leakage resistance. Here again more actual test data are necessary.

It is recognized, of course, that the earth is a nonhomogeneous material in which the conducting particles are separated by more nonconductive particles. Many nonhomogeneous materials do not obey Ohm's law but rather decrease in resistivity as the current density increases. This is probably true of most types of soil. This probably explains the decrease in the ratio of impulse to 60-cycle impedance with increasing values of crest current, as found in Figure 4 of Mr. Bellaschi's paper. This suggests the need for tests on larger diameter rods. Such tests may possibly reveal that our standard ground-rod diameters are wholly inadequate and may even suggest new methods of grounding.

Mr. Hagenguth pointed out in his discussion that the impulse impedance is probably zero at the start of the surge and increases rapidly to well above the 60-cycle values during the first fraction of a microsecond. The impedance then probably falls to a value in the vicinity of the leakage resistance. As suggested by Mr. Hagenguth, this is of particular importance on low-voltage lines since the insulation sparkover voltages would be definitely exceeded. This point bears some further investigation.

Mr. Bellaschi's paper is an early contribution in a field that requires some extensive pioneering. It is to be hoped that he and others will carry the work forward.

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Vector Equations from Laboratory Data

To the Editor:

The following methods have been found convenient in numerical vector calculations from data taken by means of voltmeters, ammeters, and wattmeters. The methods are easily applicable to any number of phases (balanced or unbalanced), wherever the wave form is such that the voltages and currents can be represented by vectors.

The information will be presented in three parts. Part A will present vector equations for voltages and currents, obtained from instrument readings, in a form which is most convenient for numerical calculation by means of a slide rule; part B will present the theory for making the calculations most conveniently by slide rule; and part C will illustrate the numerical use of parts A and B.

PART A. VECTOR EQUATIONS

Single-Phase A-C Circuit. Assume a load consisting of any combination of resistance, inductance, and capacitance in a single-phase circuit, and assume that the line voltage E, the total current I, and the total power P have been determined with voltmeter, ammeter, and wattmeter in the usual manner. We shall represent vectors of voltage and of current in bold-face characters as $\boldsymbol{E}$ and $\boldsymbol{I}$, and their respective scalars in italic characters, as E and I. Refer to Figure 1. $\boldsymbol{E}$, taken as reference, represents the voltage across the potential coil of the wattmeter; $\boldsymbol{I}$ represents the current through the current coil of the wattmeter; and θ is the phase angle from $\boldsymbol{E}$ to $\boldsymbol{I}$.

The vector equation for the current can be written, in rectangular co-ordinates, in the well-known form

$$\boldsymbol{I}=I'+j\cdot I'' \text{ amperes} = I\cdot\cos\theta+j\cdot I\cdot\sin\theta \text{ amperes} \quad (1)$$

which in terms of E, I, and P can be written as

$$\boldsymbol{I}=\frac{P}{E}\mp j\cdot\frac{\sqrt{(E\cdot I)^2-P^2}}{E} \text{ amperes} \quad (2)$$

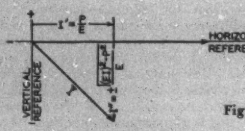

Figure 1

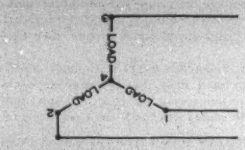

Figure 2. Three-phase three-wire unbalanced loads, having unbalanced line voltages of which the phase sequence is 1–2, 2–3, 3–1

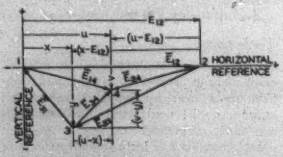

Figure 3. Vector diagram showing the vectors and their components in rectangular co-ordinates for the line voltages and phase voltages of the circuit shown in Figure 2

In equation 2 the plus sign is used if the current leads the voltage, and the minus sign is used if the current lags the voltage.

If, for this same circuit, the current had been taken as the reference, the equation for the voltage would have been

$$E = \frac{P}{I} \pm j \cdot \frac{\sqrt{(E \cdot I)^2 - P^2}}{I} \text{ volts} \qquad (3)$$

In equation 3 the plus sign is used if the voltage leads the current, and the minus sign is used if the voltage lags the current.

Three-Phase Circuit. Now we shall examine a polyphase circuit, and to express the maximum information in a given space we shall consider a three-phase three-wire wye circuit, as shown in Figure 2, with unbalanced loads and with unbalanced line voltages having a phase sequence 1–2, 2–3, 3–1. We assume that each line voltage, each phase voltage, each phase current, and each phase power has been determined by the proper instruments and recorded; and we wish to determine from these data the vector equation for each voltage and for each current. Figure 3 shows a vector diagram for the line voltages and for the phase voltages, using line voltage E_{12} as reference.

From Figure 3, using the two right triangles of which y is the altitude, we get

$$x = \frac{E_{12}^2 + E_{13}^2 - E_{23}^2}{2 \cdot E_{12}} \qquad (4)$$

$$y = \pm \sqrt{E_{13}^2 - x^2} \qquad (5)$$

Similarly from Figure 3, using the two right triangles of which v is the altitude, we get

$$u = \frac{E_{12}^2 + E_{14}^2 - E_{24}^2}{2 \cdot E_{12}} \qquad (6)$$

$$v = \pm \sqrt{E_{14}^2 - u^2} \qquad (7)$$

The vector equations for the line voltages are

$$E_{23} = E_{12} + j \cdot 0 \text{ volts} \qquad (8)$$

$$E_{43} = (x - E_{12}) + j \cdot y \text{ volts} \qquad (9)$$

$$E_{31} = -x - j \cdot y \text{ volts} \qquad (10)$$

and those for the phase voltages are

$$E_{14} = u + j \cdot v \text{ volts} \qquad (11)$$

$$E_{24} = (u - E_{12}) + j \cdot v \text{ volts} \qquad (12)$$

$$E_{34} = (u - x) + j \cdot (v - y) \text{ volts} \qquad (13)$$

To get the vector equations for the phase currents from the instrument readings we proceed as we did for the current in the single-phase case. Thus

$$I_{14} = \frac{P_{14}}{E_{14}} \pm j \cdot \frac{\sqrt{(E_{14} \cdot I_{14})^2 - P_{14}^2}}{E_{14}} \text{ amperes} \qquad (14)$$

is the vector equation of I_{14} *relative to its own voltage as reference*. To write the complete vector equation for I_{14} relative to the reference E_{12} we must multiply equation 14 by $\cos\gamma + j \sin\gamma$, where γ is the angle from the reference E_{12} to the vector E_{14}. But

$$\cos\gamma + j \sin\gamma \equiv \frac{E_{14}' + j \cdot E_{14}''}{E_{14}} \qquad (15)$$

so the complete vector equation for I_{14} is

$$I_{14} = \left[\frac{P_{14}}{E_{14}} \pm j \cdot \frac{\sqrt{(E_{14} \cdot I_{14})^2 - P_{14}^2}}{E_{14}}\right] \cdot \left[\frac{E_{14}' + j \cdot E_{14}''}{E_{14}}\right] \text{ amperes} \qquad (16)$$

and the equations for the other two phase currents are

$$I_{21} = \left[\frac{P_{21}}{E_{21}} \pm j \cdot \frac{\sqrt{(E_{21} \cdot I_{21})^2 - P_{21}^2}}{E_{21}}\right] \cdot \left[\frac{E_{21}' + j \cdot E_{21}''}{E_{21}}\right] \text{ amperes} \qquad (17)$$

$$I_{34} = \left[\frac{P_{34}}{E_{34}} \pm j \cdot \frac{\sqrt{(E_{34} \cdot I_{34})^2 - P_{34}^2}}{E_{34}}\right] \cdot \left[\frac{E_{34}' + j \cdot E_{34}''}{E_{34}}\right] \text{ amperes} \qquad (18)$$

Here again the plus sign is used before the radical sign if the current leads its voltage, and the minus sign is used if the current lags its voltage.

We have the vector equations for the line voltages, the phase voltages, and the phase (line) currents in a form in which they are easy to calculate numerically. It now remains to show that such calculation can be done very easily on one of the commonly used slide rules, say a polyphase duplex.

PART B. DERIVATION OF METHOD OF CALCULATION

If we want to calculate $\sqrt{a^2 \pm b^2}$ on a slide rule we rearrange to

$$\sqrt{a^2 \pm b^2} \equiv b \cdot \sqrt{\left(\frac{a}{b}\right)^2 \pm 1} \qquad (19)$$

the use of which is illustrated in a later paragraph. This method for the numerical calculation of $\sqrt{a^2 \pm b^2}$ can be extended to $\sqrt{a^2 \pm b^2 \pm c^2 \pm \ldots \pm n^2}$ and to $a^2 \pm b^2 \pm c^2 \pm \ldots \pm n^2$ where n is the nth term. However we shall extend the theory, for present purposes, only to $\sqrt{a^2 \pm b^2 \pm c^2}$ and to $a^2 \pm b^2 \pm c^2$. The expression $\sqrt{a^2 \pm b^2 \pm c^2}$ can be rearranged to

$$\sqrt{[\sqrt{a^2 \pm b^2}]^2 \pm c^2} \equiv \sqrt{\left[\frac{b\sqrt{\left(\frac{a}{b}\right)^2 \pm 1}}{c}\right]^2 \pm 1} \qquad (20)$$

and if the result thus obtained is squared we of course get $a^2 \pm b^2 \pm c^2$.

PART C. ILLUSTRATION

We now illustrate the use of equation 19 to calculate the numerical vector equation for the single-phase current I in equation 2 from a voltmeter reading $E = 120$ volts, an ammeter reading $I = 8$ amperes, and a wattmeter reading $P = 420$ watts, for an inductive load. In accordance with equation 19 we rearrange equation 2 to the form

$$I = \frac{P}{E} - j \cdot \frac{P\sqrt{\left(\frac{E \cdot I}{P}\right)^2 - 1}}{E} \text{ amperes} \qquad (21)$$

and make the following settings on the slide rule: bring left index of C scale in line with 120 on D scale; read

$$P/E = 420/120 = 3.50$$

on C scale in line with 420 on D scale (this gives the real part of I); bring hairline of runner in line with 8 on C scale; bring 420 on slide in line with hairline of runner; read

$$E \cdot I/P = 120.8/420 = 2.285$$

on D scale at left index of C scale; read

$$(E \cdot I/P)^2 = 5.22$$

on A scale in line with left index of B scale; to subtract 1, move slide left until left index of B scale is at 4.22 on A scale; read

$$\sqrt{(E \cdot I/P)^2 - 1} = \sqrt{4.22} = 2.05$$

on D scale at left index of C scale; move hairline of runner to 420 on C scale, which gives

$$P \cdot \sqrt{(E \cdot I/P)^2 - 1} = 863$$

* This method for determining numerically $\sqrt{a^2 \pm b^2}$ on a slide rule has appeared several times in print, but this author has never seen published any mention that this can be extended to calculate numerically on a slide rule $\sqrt{a^2 \pm b^2 \pm c^2 \pm \ldots \pm n^2}$ or to calculate $a^2 \pm b^2 \pm c^2 \pm \ldots \pm n^2$.

on D scale; bring 120 on slide in line with hairline of runner; read

$$\frac{P\cdot\sqrt{(E\cdot I/P)^2-1}}{E}=7.19$$

on D scale, at left index of C scale. We now have determined easily, quickly, and accurately the complete numerical expression for the current I, which is

$$I=3.50-j\cdot 7.19 \text{ amperes} \qquad (22)$$

relative to its own voltage as reference.

The numerical value of y in equation 5 and of v in equation 7, as well as the numerical equations of the polyphase currents in equations 16, 17, and 18, are quickly and easily determined by this method.

To illustrate the use of $a^2=b^2+c^2$ we shall determine the numerical value of x in equation 4 for three unbalanced three-phase line voltages read on voltmeters as $E_{12}=270$ volts, $E_{23}=240$ volts, and $E_{31}=200$ volts, having phase-sequence 1–2, 2–3, 3–1, and using E_{31} as reference.

Substituting these numerical values into equation 4 we get

$$x=\frac{E_{12}^2+E_{31}^2-E_{23}^2}{2\cdot E_{31}}=$$

$$\frac{(270)^2+(200)^2-(240)^2}{2\cdot(270)}=102.4 \qquad (23)$$

The result $x=102.4$ is obtained by making the following slide-rule settings: set 200 on the C scale in line with 270 on the D scale; read

$$\left[\frac{270}{200}\right]^3=1.820$$

on A scale at left index of B scale; to add 1 set left index of B scale in line with 2.820 on left half of A scale; set hairline of runner over 200 on C scale; set 240 on C scale under hairline of runner; read

$$\left[\frac{\sqrt{(270)^2+(200)^2}}{240}\right]^3=1.960$$

on A scale at left index of B scale; set right index of B scale in line with 0.960 on right half of A scale; set hairline of runner over 240 on C scale; read on A scale in line with hairline of runner

$$(270)^2+(200)^2-(240)^2=55{,}300$$

set $2\cdot(270)=540$ on left half of B scale under hairline of runner; read

$$\frac{(270)^2+(200)^2-(240)^2}{2\cdot(270)}=102.4$$

on A scale at left index of B scale. This is the result desired.

Having the numerical value of x and of y, we can write immediately the vector equation for each of the line voltages in equations 8, 9, and 10. Then using the method illustrated we can determine quickly the value of u and of v for the phase voltages, and these along with x and y substituted into equations 11, 12, and 13 give the numerical equations for the phase voltages.

The method has been applied to a three-wire wye system with unbalanced line voltages and unbalanced loads, to show how simple its use is for such a case. For balanced conditions, however, the equations reduce to even simpler form, as can be determined easily from an examination of the equations. Furthermore, the methods can be extended to six or more phases.

This method of deriving numerical vector equations for voltages and currents does not require the use of angles or functions of angles, which are rather inconvenient to use either on a slide rule or in tables; the method can be applied quickly; and it is more accurate than other methods which use a slide rule to obtain the same results.

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Voltage Calculation

To the Editor:

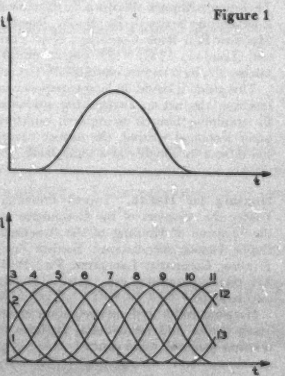
In the November 1941 issue of *Electrical Engineering*, pages 562–3, George P. Hobbs questions the rigor of the equation

$$i=dq/dt$$

on the grounds that q is not a continuous variable because it is always made up of a certain number of indivisible electrons. Mr. Hobbs' perplexity arises because he has considered that the electron is a point concentration of electric charge with infinite charge density at one point and zero charge density elsewhere. Actually, when we picture an electron as a particle, we should think of it as occupying a volume of which the boundary is somewhat fuzzy, but of which the radius is in the neighborhood of 10^{-13} centimeter. Within this volume, the charge density is finite, and thus when we analyze the conduction current in detail, we find that q is continuous along with t.

Let us consider the definition of conduction current carefully. We first set up a specific area such that the charges pass through it from one side to the other. In a wire, we usually select a cross-section of the wire as this area. Then we determine the rate at which charge crosses this area and we call this rate the current. When one of Mr. Hobbs' point electrons crosses this area, we of course get an infinite rate because we have a definite nonzero charge crossing the boundary area in an infinitesimal time. On the other hand, one of our volume-occupying electrons takes a certain nonzero time to cross the boundary area, and the rate is finite. To show this more clearly, consider some particular instant when part of the electron has crossed the boundary. In the next infinitesimal instant of time, dt, the electron moves a distance dx through the boundary area. The charge which crosses the boundary area in this infinitesimal time is then the charge in the dx-thick slice of the electron. Since we have postulated a finite charge density, the charge in this slice will be infinitesimal and the derivative dq/dt will be finite. The contribution of each electron to the conduction current would then be in the form shown in Figure 1, and the total conduction current would be the sum of such curves for all the electrons involved.

Figure 1



It is well at this point to consider the tremendous numbers of electrons involved in the conduction process. When a current of one ampere flows in a circuit, 6.24×10^{18} electrons pass through the boundary area every second, and if the wire is American Wire Gauge number 18, all the electrons in the wire need move only 0.009 centimeter in order that this many electrons cross the boundary area! At this velocity, each one would take about 2×10^{-15} seconds to pass completely through the boundary, and if the electrons crossed the boundary one at a time and at equal intervals, there would be about 1.6×10^{-19} seconds between the transit of each electron. This means that about 14,000 electrons would be in various stages of crossing the boundary area at any instant of time, so the total current curve would be the sum of individual curves as shown in Figure 2, except that between curves 1 and 13 there should be 14,000 curves instead of the few shown. The sum of all these would be exceedingly constant, certainly constant enough for practical purposes.

Actually the electrons in a metal are dashing about at velocities which range from zero up to values greatly in excess of the velocity just given. Consequently great numbers of electrons are crossing the boundary area in both directions at high velocities. Then the conduction current can be thought of as the small difference between two large currents flowing in opposite directions. Neither of these large currents is entirely steady because the motions of the electrons are somewhat erratic. As a result, the conduction current will have slight variations in value, not because of the passage of individual electrons, but because of the momentary passage of a few hundred or a few extra hundred thousand electrons in one direction or the other. Even these variations are usually of no

practical importance, but when we try to amplify very weak signals, the "noise" created by these statistical fluctuations may be stronger than the signal and may block it out. For this reason, both experimental and theoretical studies have been made of the statistical variations in current.

Mr. Hobbs' difficulty is thus removed by considering an electron as a volume-occupying particle. Such a conception does not explain all the actions of electrons, but whether we think of the electron as a particle or as a specific bundle of electromagnetic energy, we think of it as a "smear" rather than as a point.

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NEW BOOKS • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

Waves—a Mathematical Account of the Common Types of Wave Motion. By C. A. Coulson. Oliver and Boyd, London, England, and Edinburgh, Scotland, 1941. 156 pages, diagrams, etc., 7½ by 5 inches, cloth, 5s.

As many different kinds of wave motion as possible are discussed as one whole, in an elementary way. Starting from the standard equation of wave motion, the author investigates waves on strings, in membranes, bars and springs, and in liquids, sound waves, and electric waves; concluding with a chapter on some general properties of waves.

The Radio Amateur's Handbook. 19th edition. By the headquarters staff of the American Radio Relay League. Published by the American Radio Relay League, Inc., West Hartford, Conn. Paper, $1.00; buckram, $2.50.

The 1942 edition, comprehensively covering the amateur radio field, has been revised in an endeavor to meet the present need for a simple, nonmathematical, and thorough text on the theory, design, and operation of radio communication equipment, which also provides construction nformation on tested and proved amateur apparatus. The data given attempt to represent the best in current amateur practice.

What is Mathematics? By Richard Courant and Herbert Robbins. Oxford University Press, London, New York, and Toronto. 521 pages, $3.75.

The study of mathematics is presented in an attempt to make it comprehensible as an organic whole and as a basis for scientific thinking and acting. The authors state that since it presupposes mathematical knowledge of only high-school level, it is popular in its approach to mathematics, although it is intended for both beginners and scholars.

Plastics Catalog, 1942. Published by Plastics Catalogue Corporation, New York, N. Y., $5.00.

The new catalog and directory attempts to present progress in the development and use of plastics during the past year, consolidated with that of other years with a new section devoted to the use of plastics in defense. The volume is divided into nine sections: plastics in defense, materials, plastics engineering, production operations, machinery and equipment, laminates and vulcanized fiber, plastic coatings, synthetic fibers and rubbers, and index and directory, which includes bibliography, manufacturers, and trade names. New charts on plastics properties, solvents, and plasticizers are presented.

Index to ASTM Standards, Including Tentative Standards. Issued by the American Society For Testing Materials, Philadelphia, Pa.

An index to the society's 1,043 specifications and tests in numerical sequence of their serial designations as of December 1941 is here presented. The publication is available without charge from ASTM headquarters, 260 South Broad Street, Philadelphia, Pa.

Trains in Transition. By L. Beebe. D. Appleton-Century Company, New York and London, 1941. 210 pages, illustrated, 11½ by 8 inches, cloth, $5.00.

The third of Mr. Beebe's books on American railroading is concerned with changes in practice and equipment in recent years, especially the effects of the Diesel-electric locomotive, light-weight cars, and air-flow design.

Technical Report Writing. (Chemical Engineering Series.) By F. H. Rhodes. McGraw-Hill Book Company, New York and London, 1941. 125 pages, charts, tables, 9½ by 6 inches, cloth, $1.50.

This guide is based on long experience in teaching the art to engineering students. By confining himself to reports, omitting other technical writing, the author covers the subject thoroughly in a small book.

Housing for Health. Papers Presented Under the Auspices of the Committee on the Hygiene of Housing of the American Public Health Association. Science Press Printing Company, Lancaster, Pa., 1941. 221 pages, diagrams, etc., 9 by 6 inches, paper, $1.00.

Housing codes and surveys, slum clearance, health and recreational facilities in housing projects, noise control, house construction, and social implications are among the topics dealt with by various authorities.

Handbook for Civilian Defense. By H. Mayer-Daxlanden. Civilian Advisory Service, 41 Park Row, New York, 1941. 88 pages, illustrated, 9 by 6 inches, paper, $1.00.

This elementary handbook for civilian-defense workers deals in a simple, concise manner with all phases of civilian-defense training and organization for war conditions; and also shows the value of such training for various peacetime emergencies and natural disasters.

Civil Defence. By C. W. Glover. Third edition, revised and enlarged. Chemical Publishing Company, Brooklyn, N. Y., 1941. 794 pages, illustrated, 9 by 5½ inches, cloth, $16.50.

Presents, with working drawings, the methods required for adequate protection against aerial attack. Includes material on bombs and their effects, war gases, camouflage, civilian instruction, training of Air Raid Precaution personnel, and cost estimates (British figures), in addition to considering the construction of all types of protective buildings and shelters. Bibliography.

Gaseous Conductors, Theory and Engineering Applications. (Electrical Engineering Texts.) By J. D. Cobine. McGraw-Hill Book Company, New York and London, 1941. 606 pages, illustrated, 9½ by 6 inches, cloth, $5.50.

Discussion of the fundamental principles of physics involved in the conduction of electricity in gases, and their application in engineering. Covers the principles essential to an understanding of conduction phenomena, such as the kinetic theory of gases, ionic motion, atomic structure, ionization and deionization processes, emission phenomena, and space charge effects.

Engineering Electricity. By R. G. Hudson. Third edition. John Wiley and Sons, New York, 1941. 284 pages, illustrated, 8 by 5 inches, leather, $3.00.

Written primarily for technical students not specializing in electrical engineering, this textbook presents an outline of the fundamental principles and of the applications of electricity and magnetism most frequently encountered in engineering practice. Practice problems with answers.

Electrical Wiring Specifications. Edited by E. Whitehorne. McGraw-Hill Book Company, New York and London, 1941. 181 pages, illustrated, 9½ by 6 inches, cloth, $2.50.

A simple working guide for those concerned with designing wiring installations, laying out systems, and preparing specifications for any given job in an industrial, commercial, or residential building.